REPORT

ON THE

GEOLOGY OF VERMONT:

DESCRIPTIVE, THEORETICAL, ECONOMICAL,

AND

SCENOGRAPHICAL;

BY

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IN TWO VOLUMES.

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VOL. I.

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Were it not for these subterranean streams of water which impart to the air* in wells a portion of the heat contained in them, as well as to keep the water at a higher temperature, much inconvenience would be experienced by the accumulation of ice in wells that were exposed to the intense cold of our northern winters.

I will not tire your patience longer, but make a suggestion of a practical nature, and close this epistle, which is already extended too far. If the preceding theory be correct, those who experience difficulty in keeping ice in houses erected upon a gravelly terrace—as is often the case—would do well to copy from this example in nature, and, before erecting an ice-house, make an excavation in the earth, and place therein in a slanting direction, like an inverted roof, alternate strata of compact clay and some porous material, like pebbles, and have the clay (or sound plank in its stead) extend beyond the walls of the house to conduct off the heated air that might arise and otherwise pass up through the porous soil into the ice-house. But if this is considered too burdensome and expensive an operation, I would suggest to those who have gardens embracing clay soil and sandy loams, and would build an ice-house therein, that they put it upon the former, and plant their early peas and watermelons in the latter—for the warm air that permeates the porous earth will prove injurious in the one case, but be beneficial in the other.

Respectfully yours,

ALBERT D. HAGER.

Having shown the character and disposition of the various sorts of loose materials that cover the surface, let us see what marks the rocks exhibit of having been worn down and torn away in order to furnish so much detritus.

EROSIONS OF THE SURFACE.

Although the evidence of powerful denudation is everywhere most obvious, in all the hilly parts of New England, yet we must not hence infer that all the valleys and other inequalities were thus produced. For where we find the stratified rocks dipping in opposite directions, so as to form anticlinal and synclinal axes, we see proof that the commencement of these inequalities was the original tilting and folding of the strata. But since these movements, the work of erosion has been enormously great. Of its amount we can judge better after detailing the facts.

In treating of the loose materials produced by erosion, we have gone no further back than the tertiary, for since that time the materials have almost without exception been brought into their present forms and positions. But erosions had a far earlier commencement, dating from the period of the first consolidation of the strata that are worn away; and a part of the materials thus produced have been used, it may be more than once, to form rocks, which in their turn have been reduced to an unconsolidated state. As far back, then, as the time when the oldest hypozoic and metamorphic rocks were first hardened and elevated, we must extend our thoughts, if we would learn how great the work of erosion has been in Vermont. This carries us back an immense period into the past, for some of these rocks are among the oldest on the globe.

The agents of erosion are somewhat numerous, and ceaselessly active in appropriate circumstances. All the ingredients of the atmosphere—oxygen, nitrogen and carbonic acid—act directly upon the rocks, producing disintegration at the surface. Oxygen is probably the most efficient agent.

* Air of a low temperature, coming in contact with water of a higher temperature, is rarified by the additional heat imparted to it, and rises at once and communicates to the atmosphere in the well this acquired heat, and thus it is kept above the freezing point.

But the power of the atmosphere to produce disintegration would be small without the aid of water. This is the grand agent in the work, and without it other agencies would be comparatively inefficient. Carbonic acid especially becomes very efficient when dissolved in water, which is thus made capable of dissolving nearly every sort of rock.

Water alone does, indeed, possess the power of dissolving most rocks, though in minute quantity. It is remarkable also for its power of penetrating rocks, not only finding its way into all fissures, but by means of capillary attraction penetrating far into the solid mass, as we have already shown. In this way we often find the rocks to the depth of several feet, so thoroughly disintegrated that currents of water, and especially if loaded with ice, will sweep off the loosened mass and thus prepare a new surface to be acted upon by the water, or even the vapors of the atmosphere.

The power of water in the frozen state—as glaciers, icebergs and icefloes—is very great: but still greater when it exerts its expansive force in freezing. Gunpowder hardly equals it; and probably a large part of the loose materials scattered over the surface as bowlders, are first loosened from the ledges by the freezing of water in the crevices of the ledges. Even though they get only an infinitesimal start the first year, each subsequent year—because the crevices are widening—will witness an increase of the work.

By these various agents have the materials been got into readiness to be transported to their present situations, chiefly by the ocean and rivers. The greatest part of the work has probably been done by the waves, tides, currents and icefloes of the ocean, as the land has sunk and risen again and again, thus making every foot of its surface repeatedly and for long periods the shore of the ocean. The drainage of the land, also, by rivers, accomplished again and again by these vertical movements, has worn out gorges and valleys of great depth, and the work has not yet ceased. Several of the agencies have often acted together, and we are rarely able to say how much has been done by each. The effects which they have produced in Vermont, singly or conjointly, we shall now attempt to show by examples.

THE GORGE AT BELLOWS FALLS.

On the east side of Connecticut River at Bellows Falls, Kilburn Peak rises very precipitously 828 feet above the river at the top of the falls, and crowds close upon it; while on the west side, the country rises rapidly towards the Green Mountains, to a still greater height. One can hardly look at the narrow passage of the river through this gorge, without awakening the inquiry whether it has not been worn out by the river, or some other agency. If so, the valley above the spot must once have formed a lake, which, according to the present levels, would be 800 feet deep. Starting with Kilburn Peak and going northeasterly, we shall find the watershed between the Connecticut and Merrimac valleys extending almost in a strait line to Franconia, and then turning more to the right to Mount Washington. The lowest point in this ridge south of the White Mountains is on the Northern Railroad from Concord to Lebanon, in Union, where it is 682 feet above Connecticut River at Lebanon, and 822 feet above the river at Bellows Falls. On the Vermont side of the river the country rises to the Green Mountain ridge, and the lowest depression in it south of the latitude of the White Mountains, is on the Vermont Central Railroad at Roxbury, which is 930 feet above the river at Lebanon; the lowest point on the Rutland and Burlington road at Mount Holly being 1350 feet above the river at Bellows Falls. Hence if the Connecticut valley above Bellows Falls had been filled with water to the height of 722 feet above the present level of the river, the water would not have flowed out laterally either into the valley of the Merrimac, or of Lake Champlain. Nor can there be any doubt that there is a barrier on the north, high enough to prevent communication with the valley of the St. Lawrence.

Now it so happens that where the Northern Railroad has excavated a trench through the eastern watershed in Union, 30 feet deep and 1200 feet long, it has laid open several large pot-holes in the granite. These we consider decisive proof that a cataract once existed at this spot, since we know of no other agency that could produce pot-holes.— Both on the east and west sides of the cut we find swamps surrounded by gravel beds or modified drift, with brooks starting the one for Merrimac and the other for Connecticut River. But we see at once that these have had nothing to do with the powerful erosions that are manifest at this spot. A large stream of water must have poured over the barrier from the Connecticut into the Merrimac valley. Had the current been from the south-east the marks of river action would have been on the northwest side; but instead of this we find on that side strong evidence of drift agency, while the pot-holes are on the Merrimac side of the ridge.

On examining the west mural face and the top of Kilburn Peak, we find marks of what seems to be ancient river action, which the subsequent erosions of the drift agency did not obliterate. On account of the difficulty of distinguishing between the two agencies, or we might say between fluviatile and oceanic agency generally, all of which have been brought to bear upon this spot, we feel no great confidence in this corroboratory proof of the former outflow of water as high as Kilburn Peak.

The facts, however, that have been stated, force us very strongly to the conclusion that the Connecticut valley above Bellows Falls must have been once filled with water as high as the gorge in Union,—that is, 722 feet above the top of Bellows Falls,—and consequently that the mountains there must have been once united, and the gorge have been worn down to its present depth by fluviatile conjoined with oceanic agency. The great lake above, which once had an outlet at Union in the Merrimac valley, was subsequently drained by the way of Bellows Falls. What diverted the current from Union to Bellows Falls it may not be easy to determine, if we suppose the present levels not to have been changed. But in some other cases we have strong reason to believe that during the sojourn of the continent beneath the ocean at the drift period, gravel accumulated in valleys which on a previous continent were the beds of rivers, so that when the continent rose, the rivers had to seek out new channels. No facts at the Union gorge will sustain such an hypothesis in respect to the last submergence of the continent. Yet the change of outlet may have occurred at an earlier date; we mean at some previous submergence. It would be strange, also, if some of those plicating movements, which we know to have occurred in our country even later than the coal period, should not have somewhat affected the metamorphic strata along the Connecticut; though we think that the principal changes of level occurred at an earlier date. Yet the change of outlet under consideration may have required a vertical movement of only a few feet. Upon the whole, we think the two causes that have been suggested will reasonably explain all the changes of outlet with

which we have met in the barriers of ancient lakes. We might, however, suggest a third cause in the flux and reflux of tides and currents during the slow vertical movements of continents.

THE GORGE AT BRATTLEBORO.

Wantastoquit Mountain rises precipitously on the east bank of Connecticut River, opposite Brattleboro, to the height of 1050 feet, while on the west side the hills rise higher and higher, till they culminate in the crest of the Green Mountains. The top of Wantastoquit also shows marks of river action more decidedly than Kilburn Peak. In short, the circumstances at the two places scarcely differ, except that the hills on the west side rise less rapidly at Brattleboro. But we can hardly doubt that the Brattleboro gorge, like that at Bellows Falls, has been slowly eroded by fluviatile and oceanic agency, and that the narrow and rather irregular valley between the two places was once a deep lake. And we might say the same of several other basins on the Connecticut, where at the ends the mountains crowd close upon the river. The case at Bellows Falls is the most remarkable, because we find the exact place where the lake had once an outlet towards the east. But if we make out erosion there, no one need hesitate to admit it at any other place along the river, since everywhere else almost it must have been on a smaller scale.

ANCIENT RIVER BEDS IN CAVENDISH.

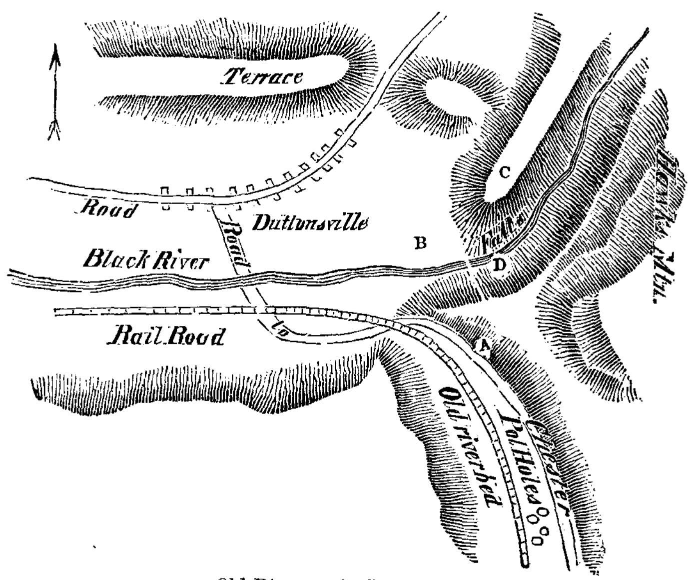
This case was described a few years since in a work on Surface Geology, already referred to frequently, and we take the liberty to transfer that account to the present Report.

Williams River and Black River, streams of nearly the same size, rise in the Green Mountains, and, running nearly parallel, empty into Connecticut River—the former two or three miles north of Bellows Falls, and the latter ten or eleven miles further north. Through most of their course, they are separated by mountains rising sometimes to near a thousand feet in height. Yet there are at least two gulfs, the Duttonsville one, and that at Proctorsville in Cavendish, connecting the valleys of the two streams, and through which Black River once flowed into Williams River—in other words, it is probable that Black River was once a tributary of Williams River. The evidence of the position I shall now present.

THE DUTTONSVILLE GULF.

The Rutland and Burlington Railroad passes up Williams River from Bellows Falls, eighteen miles to Gassett's station. There it turns to the right, and crosses to Black River through the Duttonsville Gulf. Through its whole course that gulf bears evidence, to a practiced eye, of being the former bed of a river; but just before we reach Duttonsville we find deep pot-holes in the gneiss rock, perhaps fifty feet above Black River. This old river bed, especially near Duttonsville, is choked up to the depth of several feet by terrace materials which must have been deposited during the last submergence of the continent beneath the ocean. These formed a bank so high that as the surface emerged, and a river began to run down the valley, it was turned to the left, and found a new channel to the left of the mountain lying east of Duttonsville. The following sketch, taken by the eye, will present an outline of the spot.

Fig. 101.



Old River Bed, Cavendish.

During the drainage of the country, a pond would occupy the basin B, at Duttonsville, extending up the river as far as Proctorsville, and perhaps even to Ludlow, and the water would find an outlet at the lowest point. On the north side it was kept in by a gravel terrace extending to the rocky hill C, and as stated above the old bed at A was raised by a similar deposit. The result was that the rocky ridge at D was the lowest point, and there the stream flowed over and commenced its erosion of the strata. That work has gone on till a gorge has been worn back half or three quarters of a mile, and the work is now progressing in the hard gneiss rock. According to my barometrical measurements the river falls in this whole distance as many as 183 feet.

The old river bed, after continuing about three miles towards Gassett's railroad station, forsakes the railroad track, and finds its way to the present bed of Black River some seven or eight miles below Duttonsville. But a similar bed continues as far as the Gassett station. No pot-holes indeed occur along this ravine, but we cannot doubt that a stream once flowed through it and joined Williams River. Indeed its bottom is only a few feet higher than that of the ravine just described, which branches from it to the left. Yet, since the stream must have flowed through the lowest valley at the latest period, we must regard the valley running to Gassett's as the bed of the river at an earlier date. But this subject will be referred to more at length in a subsequent paragraph.

THE PROCTORSVILLE GULF.

The bed of the ancient river at Duttonsville is 675 feet above the top of Bellows Falls. Passing from this place two miles up the Black River, we find a rather broad valley almost level, as far as Proctorsville, another flourishing village. Running nearly south from this village, we find a deep narrow ravine, cutting through the high mountain, and opening at its southern extremity into the valley of a tributary of Williams River. I

found no pot-holes in the sides of this ravine, but every other mark of a former current of water, which wore out the gorge, is seen on the surface.

The highest point in the gulf, perhaps a mile south of Proctorsville, is 117 feet above the old river bed at Duttonsville, or 792 feet above the top of Bellows Falls. At the summit, the gorge shows a deposit of terrace materials—how deep I cannot say. But the fact is sufficient to show that no stream has passed through this gorge, since the last emergence of the continent. But that Black River—or rather the progenitor of that river on a former continent—once passed through that gorge, and was, in fact, a part of Williams River, will be obvious by an inspection of the rough outline on Plate V. But at what period of antediluvian history did this take place?

If the principle above alluded to be true, namely, that where more than one lateral ravine, once the beds of rivers, open from a common valley—that which is lowest was last occupied by the stream — then the Duttonsville gulf is more recent than the Proctorsville gulf. I have inferred that the former was the bed of a stream on the continent which immediately preceded the present. Was the latter worn out during the same period; or might it have been the work of a stream on a still earlier continent—that is, the second one anterior to the present? If we knew the depths of the detritus at the summit of the Proctorsville gulf, it might aid in deciding this point. But I can hardly believe that its depth equals the difference of level between the two gulfs. If not, then the Proctorsville gulf must have been higher than the other during the period of emergence previous to the present. The country below Proctorsville, also, must have been blocked up high enough to throw the waters through the Proctorsville outlet.

The amount of erosion since that time, on such a supposition, must have been enormous, to bring the region below Duttonsville into its present state. And it would not be an improbable supposition that the Proctorsville gulf, as well as the right hand branch of the Duttonsville gulf, already described, may have been the bed of a stream on a continent earlier than the last. But I despair of being able to prove this decidedly by any facts within the reach of present observation. And yet, those detailed above do appear to me to prove at least a great difference in the ages of these two gulfs. But whether the period between them embraced a submergence of the continent, is another question. To be able to trace back with clearness erosions accomplished on even the last continent, is more than I ever expected to be able to do. The above facts come nearer to extending our vision across another mighty chasm, and witnessing events in surface geology upon a still earlier continent, than any I have ever met with. But whether this be a problem resolvable by the geologist, I am in doubt.

OTHER CASES OF OLD RIVER BEDS.

These are quite numerous, so far as we have been able to trace them out, and we have every reason to suppose that further research would bring to light many others. Those which we shall mention, but in general not attempt to describe minutely, are of two kinds as to the period in which they were formed, and the materials which have been cut through. The first class have been formed in modified drift, usually in the gravel and sand of terraces, or even in existing alluvial meadows. The second class have been formed in the solid rocks, and of course are of far earlier date than the others.

I. IN MODIFIED DRIFT.

It is frequently easy to see in alluvial meadows that the river has changed its bed, sometimes by slowly wearing away one of its banks, and sometimes by suddenly shifting to a new channel in consequence of some obstruction. In such cases the proof is obvious to the eye, but not easy to describe. We see on the spot where the old bed parts from the present one, and can follow it all the way to where it rejoins the same. These changes may sometimes be seen in some of the old terraces, as at Bellows Falls and White River Junction. The following cases have been noticed by us under this class.

1. ALONG CONNECTICUT RIVER.

1. At Bellows Falls, west part of the village.
2. At White River Junction, proceeding from White River and passing southerly so as to join the Connecticut; made evidently by White River. Marked on the Map of Connecticut River terraces. Plate III.
3. At Windsor, north of the village, half or three quarters of a mile long. Others, we think, occur between Windsor and White River Junction. Plate IV.
4. In Hanover, N. H. See Map of the Connecticut. Plate III.
5. In Orford, N. H.
6. In Newbury are several in the beautiful meadow. See Map of the terraces there. Plate V.
7. At Guildhall. See Map of the Connecticut.
8. At Colebrook, N. H. See Map of the Connecticut.

Others occur north of Colebrook, but were not observed carefully enough to be described.

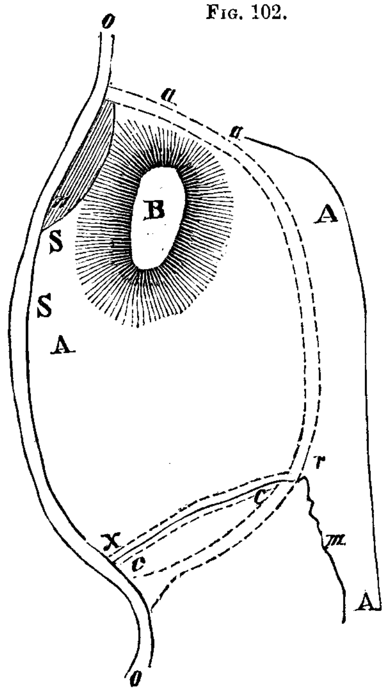
2. ON PASSUMPSIC RIVER.

In Lyndon, a mile long, near the depot village. The old bed rather belongs to a tributary. See Map of the terraces on the Passumpsic. Plate VI.

3. ON POULTNEY RIVER.

Prof. Adams in his second annual Report, p. 156, has given a detailed account of a remarkable change effected in this river, three miles northwest of the village of Fairhaven, during a freshet in 1783.—

Fig. 102.



See Fig. 102. The river previously had run through a rocky gorge over a fall, because probably its old bed on a previous continent had been filled with sand. But having been diverted back again, by human agency it is said, into the sand, it soon cleared out its old channel and left the falls dry. The case is very similar to the sudden drainage of a pond in Glover, described in another place. B is a hill of talcoid schist. A A A, an alluvial plain. S S, a neck of land, across which a man run a furrow and occasioned the change in the river. *a a*, the dry falls, 150 feet high.— The old bed, mostly through rocks, extends from X, through *r*, to *a a*: but a small stream, *m r* X, occupies a part of it and empties into the present river at X. This now runs in the direction of *o* X S S *o*: the present falls being at the last designated spot. C C, is an island in the old channel.

3. On Williams River, at Bartonsville, a similar case occurred in consequence of a cut through a terrace by a railroad. A freshet cut away the rest of the terrace and turned the river into its old channel, whereby a mill was left dry and its owners recovered damages from the road.

4. ON WINOOSKI RIVER.

1. At West Waterbury. The railroad passes through it.
2. At Waterbury. See Map, Plate V.
3. At Middlesex. The railroad runs through it.

5. ON THE LA MOILLE RIVER.

1. In Fairfax. See Map, Plate V.
2. In Johnson, east of the village; one mile long, north side of the village, running round a large terrace.

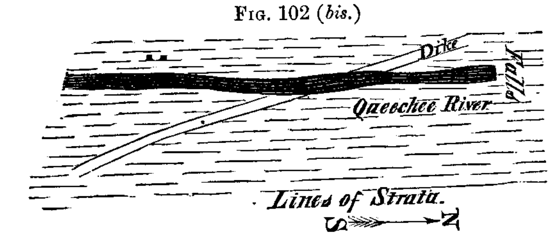
II. IN ROCKS OLDER THAN DRIFT.

All the preceding cases of changes in the beds of rivers have occurred during the alluvial period. We add others, which, like those at Bellows Falls, Brattleboro and Cavendish, are of far earlier date, and have been formed in solid rock. Some of them, indeed, have no connection with existing rivers.

1. The case just referred to at Bartonsville furnishes an example. For the old bed of the river, being filled with sand and gravel probably during the sojourn of the land beneath the sea, compelled the stream, on the rise of the continent, to cut out a new channel through the rocks, which it abandoned, when, by the help of the railroad, it was able to scoop out its old bed.

2. On the Quechee River at Hartford the river passes through a gorge a mile long, one side of which is a continuous wall one hundred feet high. A mile above the gulf are falls twenty feet high, with pot-holes, and probably the river has worn back that distance. This gulf has been supposed to follow the course of a trap dike. But Fig. 102, *bis*, will show that the dike crosses the river.

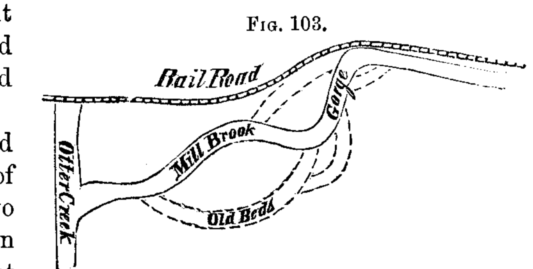
Fig. 102 (*bis.*)



3. In Shrewsbury, near Cuttingsville. One of our number (A. D. Hager) thus describes this example: "About two miles north of Cuttingsville is an old river bed now occupied by the railroad. It is in Shrewsbury, near the west line. The length of the old bed is about three quarters of a mile. The river now runs through a deep gorge in slaty rock, seventy-five feet deep in some places. Terraces abound at the side of the gorge near where the old bed is situated."

4. In Clarendon. This occurs on Mill Brook, a branch of Otter Creek, a little east of the Western Vermont Railroad near the principal village. The stream has cut a gorge through the rock eighty-five feet deep, and three old beds can be traced, as is shown on the sketch Fig. 103, furnished by A. D. Hager, who alone of our number has seen this case.

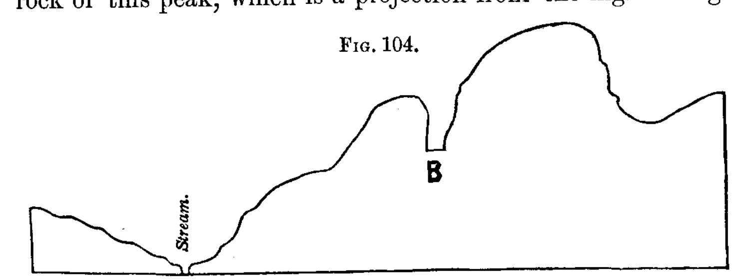
Fig. 103.



In Clarendon.

5. In the east part of Pittsford, we were carried to an old river bed by B. F. Winslow, Esq. It lies on the west face of the steep mountain sometimes called East Peak, a mile or two east of the iron furnace on Furnace River. The gorge is on the west face of this steep mountain, about six hundred feet above the river, and half a mile long, running nearly north and south. The north end opens into the valley of Furnace River, somewhat east of the spot already described for its remarkable exhibition of powerful denuding agencies, and the south end opens into the same valley. It is in fact a gorge two or three rods wide, and from thirty to one hundred feet deep, cut into the hard quartz rock of this peak, which is a projection from the higher range to the east, that has withstood all denuding agencies and preserved this remnant of an old river bed,—probably the bed of Furnace River, when it was six hundred feet above its present level. The sketch in Fig. 104, B, which is a section crossing this mountain and the gorge, east and west, will give an idea of its position. When occupied by the stream—as it must have been for an immense period to wear out a channel probably once a hundred feet deep throughout, in a rock which bids defiance to almost all agencies,—the broad valley to the west, now at least six hundred

Fig. 104.



Old River Bed, Pittsford.

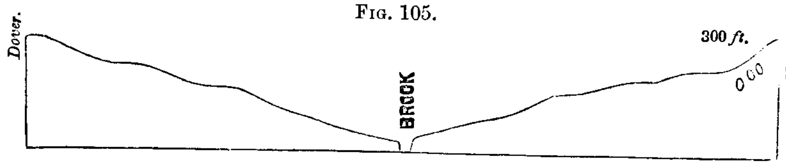
feet deeper than the gorge, must have been filled so as to cause the water of the river to flow through the gorge. What a vast amount of denudation must have since taken place! When we think of the antiquity of this old ruin, how do those of Egygt and Nineveh seem but the work of yesterday!

POT-HOLES.

The existence of pot-holes in ledges of rock we have always regarded as proof that a cataract once existed at the spot, for in no other way can their formation be explained. No movement of waves or tides in the ocean can account for them. Hence, wherever they occur, rivers must have existed. Generally, but not always, other proofs are found, with the pot-holes, of ancient rivers; but these excavations are the best evidence. A few examples will be given, and from the ease with which these were found, we infer that longer examination would bring others to light.

1. At the soapstone quarry in the west part of Newfane, a spot about 2600 feet above the ocean. The soapstone, in connection with huge masses of serpentine, forms the crest of a hill in the extreme westerly part of Newfane, on whose west side the pot-holes occur, as shown in Fig. 105. The slope of the hill is as represented on the figure, descending three hundred feet to a brook, on whose west side is a corresponding hill in Dover.

Fig. 105.



The conclusion seems fair, that the stream once ran where the pot-holes now are, and that subsequently it has worn out the valley in which it now runs, to the depth of three hundred feet. Other agencies may have aided in the work, as the great width of the valley perhaps indicates. The ocean may have done something, but we think that probably the stream itself—which is of considerable size, and capable, when swollen, of powerful erosion—has mostly disposed of the materials.

2. Pot-holes occur in Wardsboro on the farm of Eliab Scott, one half mile west of his house. Three of them may be seen within an area of four rods, the largest 3 feet across, and 4 feet deep to the gravel lying in the lower part. The rock is talco micaceous schist. The spot (says C. H. Hitchcock who has alone visited it) is just where a current would go from Wardsboro to Newfane Soap Stone. Very probably the pot-holes at these two localities indicate two cataracts in one and the same ancient river. The Wardsboro locality is 1500 feet above the ocean.

3. Other pot-holes still larger occur in Wardsboro, in a depression in the dividing ridge between Deerfield and West Rivers. This point is 2235 feet above the ocean, and here a branch of West River takes its rise, running northwesterly to a branch of Deerfield River, running southerly. The holes occur a little north of the crest where the surface slopes in that direction; and thus is it made probable that the stream which produced them must have flowed northerly: and yet it was suspected that pot-holes occur also on the southern slope, though not actually found. If so, a stream must once have flowed southerly over the spot. Nor would it be strange if at different periods of the world's history there might have been currents in different directions. For at this spot, some 40 feet below the pot-holes, drift striæ are seen. This fact shows that the holes were excavated a long time before the striæ were made.

This spot has been visited by only one of us (C. H. H.), and he probably had not time to trace out all the relations of this case. He was accompanied to the spot by Mr. H. P. Goodell, Principal of a school in Wardsboro, and several others who united in efforts to clear out the gravel from the largest of those holes. Mr. G. paid a subsequent visit to the spot, and thus describes it: "Since our visit to the pot-hole the sand and gravel have been removed, and at the bottom, in some coarse sand, two stones, real *hard-heads*, smooth as polished marble, were found. They are not spherical, but nearly twice as long in one direction as the other. One weighs one and a quarter pounds, the other 46¼ pounds. The hole is 10 feet 8 inches deep, in diameter 2½ feet. Immediately behind the hole the rock rises twenty feet; some twenty-five or thirty rods further back is an elevation of two hundred feet. The form of the hole is screw like, the thread making three complete turns before reaching the bottom, which is shaped like that of a caldron kettle."

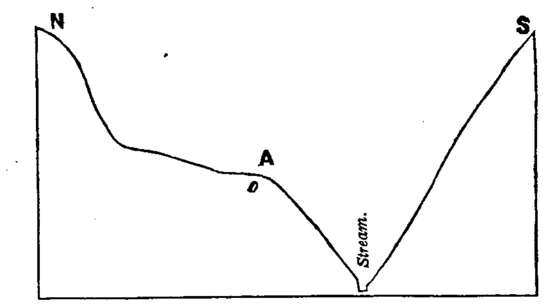
The rock here is the peculiar gneiss of the Green Mountains, dipping 35° E. The most important inference from the case is that a river once and for a long time poured over this spot, which in height is nearly equal to the average elevation of the Green Mountains.

4. In Wallingford, 150 feet above Otter Creek, is another case of pot-holes.

5. Another example is in West Hartford, on the Central Railroad. The spot is 60 feet above White River, and the pot-hole 17 feet deep. From this hole was extracted the beautiful sphere of granite, 2 feet 4 inches in diameter, which the visitor will find lying in front of the College buildings in Burlington—of which we have never seen the equal. Two of them were found; but one was buried in the railroad.

6. A more important case occurs in Plymouth, not far to the north of Tyson's Furnace. A large pond is here planted amid the hills, as much as 1100 feet above the ocean. On its east side a small stream enters, along which, for one or two miles, some of the most successful gold diggings in Vermont have been opened. Just east of the pond rises a sharp ridge, whose crest slopes for the most part rapidly to the south, and terminates at the stream, as shown on Fig. 106. On the opposite side rises a corresponding hill, S. At A, about 250 feet above the lake, is a small but distinct pot-hole; and all along the crest of the hill, which slopes rapidly both east and west for 40 or 50 rods, each way from the pot hole, are the most distinct marks of water having poured over the ridge from east to west.—The tortuous channels worn out of the rock are not exactly pot-holes; but they approach that form of erosion, and, to an eye familiar with river action, are scarcely less indicative of the former presence of a river. Still further north rises a lofty hill, N, which probably protected this ridge in part from the full force of the drift agency, and therefore it retains so much evidence of fluviatile action. One perceives at once, that the stream which now runs at the foot of the hill half a mile south once poured over this crest, to the height at least of over 300 feet, and that its bed gradually moved southerly as it was worn deeper. The present outline of the surface probably gives us only an imperfect idea of the whole amount of erosion, since we cannot tell how much has been worn from the crest of the hill.

Fig. 106.



PURGATORIES.

There is another class of phenomena indicative of erosions, to which we have given some attention, but to which we hardly know what name to give. In Massachusetts and Rhode Island, however, the gorges to which we refer have received the quaint name of Purgatories. Near Newport in the latter State, where numerous transverse joints cut across the conglomerate, the action of the waves of the sea upon the matter between two joints sometimes wear it away, so that deep and long fissures are produced with perpendicular walls. These are called Purgatories. Sometimes these gulfs extend entirely through the crest of a hill, as at Sutton in Mass., and still are called Purgatories, though far away from the present ocean. It is this description of these gorges which we find in Vermont. They generally occur at the summit level of different streams; in other words, where two streams belonging to different systems of rivers take their rise. Yet the idea that these small streams, usually only brooks, produced the gorges, is absurd. They can be explained only by earlier and more powerful agencies. But we will first refer to a few examples.

1. The Dixville Notch in New Hampshire, as it has been described by D. C. T. Jackson, seems to us (for we have none of us seen it) to be a typical example. We have there a cut from 600 to 800 feet deep in nearly perpendicular strata of mica schist, through which a road runs from S.W. to N.E., and two streams take their rise, one running westerly to the Connecticut and the other easterly to the Androscoggin. In some way or other, then, we may be certain that a gulf 800 feet deep has been cut through this dividing ridge. Whether we admit or not with Prof. O. P. Hubbard, in his valuable paper on erosions in New

Hampshire (American Journal of Science, Vol. IX, N. Series), that probably trap dikes once occupied the clefts, we shall equally need some agency to remove the materials.

2. Willoughby Lake. So obvious is it that this lake—six miles long and one mile broad, and walled in on two sides by rocky ridges 1800 feet high—now occupies the place once occupied by the mountain, that no one, however little acquainted with geology, doubts that the two mountains were once united, and that they have either been separated or worn away. It is the most common explanation to say that the gulf resulted from some "violent convulsion of nature," which is the usual resort for any unusual phenomena in nature. But I could discover no evidence of any such disruption of these mountains. But the fact that here is the summit level between the waters of the Passumpsic on the east, and Lake Memphremagog on the northwest, makes it most probable that like Dixville Notch—and some other cases to be described—this is a valley of erosion of the peculiar kind called Purgatory. Our theory of the mode in which they were formed will be stated after a few more examples are given.

A fact in respect to Modified Drift at the two extremities of the Willoughby gorge deserves notice. Irregular hills of gravel and sand there rise, some of them 100 feet high. Yet the borders of the lake show nothing of this kind above the waters, and, as these are said to be very deep, we doubt if the modified drift is there. Did it fail to lodge in the gorge and accumulate at the extremities, because the waters of the ancient ocean rushed through the opening with violence, or too quietly to carry the detritus with them?

3. The gorge between Lowell and Eden. The Missisco River takes its rise in the south part of Lowell and runs nearly north through Lowell and Troy, and from thence curves around the north end of Jay Peak and runs westerly to Champlain. Passing from Lowell to Eden, we follow a principal branch of this river to its source, which is the summit level between the Missisco running north, and a branch of the La Moille, running south. Here is a gorge of considerable depth, excavated in solid rock, having the same general aspect as Willoughby and others, where water and ice were the probable eroding agents. There is a pond a little south of the summit at Eden. At its north end we find modified drift, which grows coarser as we approach the gorge. This fact seems to indicate that the current which brought in this detritus came from the south. But this point needs further examination.

South of Eden, the valley through which the current from the Troy valley might have run was perhaps that through which the La Moille now flows. Or it might have passed across from Hydepark through Stowe, &c., to the White River at Waterbury.

4. Gorge near Eagle Ledge, near where the corners of the four towns of Worcester, Calais, Woodbury and Elmore unite. The rock is here excavated to a considerable depth, and on the north a stream runs into the La Moille, and on the south the principal branch of the Winooski takes its rise, so that these two rivers were probably once connected, or rather the two bodies of water that once occupied the depressions which we now call the valleys of La Moille and Winooski; for the gorge near Eagle Ledge (we are not sure in which of the four towns it lies) is 800 feet above the present bed of the La Moille.

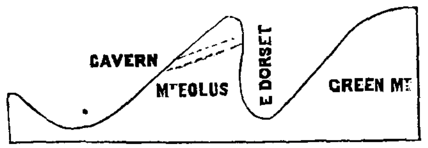
5. The Williamstown Gulf. If we pass up the Stevens branch of the Winooski to Williamstown, we shall find a pond in modified drift at the summit level, whence the second branch of White River rises and proceeds southerly. At this point is no excavation in rock, but a mile south is the gulf, cut not less than 100 feet deep through the ledges. Through this gulf the Winooski most probably once passed southerly, and was a tributary of White River. But we regret that our observations on this route have been so defective.

6. The Roxbury Summit Level. This is the highest point on the Vermont Central Railroad, and is something like a hundred feet higher than the summit level just described in Williamstown. There are no striking gorges near the summit, yet a practiced eye perceives certain marks which indicate the valley to have been one of erosion. In descending towards the Winooski, some pot-holes occur a few miles south of Montpelier, indicating the former existence of a cataract.

7. Summit level between the Battenkill and Otter Creek in East Dorset. If any one takes the Western Vermont Railroad from Rutland and goes southerly, he will find himself soon in a deep narrow valley, having the Green Mountains on his left and a part of the Taconic range on his right. At East Dorset

he will find himself at the summit level of the two streams named above, while the Taconic range there culminates in Mt. Eolus, which shows on its east and south sides strata of white limestone of immense thickness. Marble quarries are opened in it at various heights, one as high as 1500 feet above the valley. At this spot a large cavern opens into the mountain on the almost perpendicular wall, and sloping downward in a westerly direction, extends, no one knows how far (see Fig. 107), but it probably has an outlet on the west side of the mountain; for it is obviously an old river bed, such as are common in limestone regions. The figure subjoined will give an idea of its situation.

Fig. 107.



The question naturally arises, what has become of the surface over which the ancient river flowed that wore out this cavern? And it seems rational to reply that it has been worn away—that is the valley below, 1600 feet deep, has by some agency or other been worn out since that river ceased to flow. The only other supposition is, that the mountain has been lifted up. It certainly has been subject to great disturbance, and probably has been elevated; but we apprehend not since the present configuration of the surface has been produced. At least there is no evidence that Eolus has been subject to vertical movements more recently than the other parts of Vermont. The disturbance appears to have been anterior to the commencement of these erosive operations which seem to us to have furrowed out most of the valleys of the State.

Here, then, we have a deep, and for the most part a narrow valley, 50 or 60 miles long in Vermont, and extending southerly still further across Massachusetts and Connecticut, which seems to have been excavated in some way or other. At least if we admit that it was done at Dorset to the depth of 1600 feet, we may presume that in its whole length it was the work of erosion, since it is scarcely deeper in any other place. By parity of reason the other deep valleys which inosculate with this, may be imputed to a similar origin. To what agency shall we impute such a work? If we can answer this question satisfactorily, the explanation will apply equally well to the other cases of deep excavations which we have described at summit levels.

We suppose the agency to have been partly oceanic and partly fluviatile. In another place we have presented the evidence that this continent has been again and again beneath the ocean, both submergences and emergences having taken place with extreme slowness. The consequence would be, that every foot of the surface has been again and again, and for ages exposed to the erosive agency of oceanic waves and currents. Suppose, now, a mountain ridge, having a depression in its crest, to be slowly emerging from the water. While the higher parts would form islands, the winds, the tides and the currents would cause the water to rush forward and backward through the openings. If the same waters were loaded with ice, this would help on the erosion. The channels thus begun would become narrow straits at length, and when the waters had sunk low enough for the formation of rivers, they might for a time at least pass through these straits and deepen them. Raised still higher, these gulfs might become the starting place for rivers flowing in different directions, and these might in time wear out valleys of great extent. These processes, repeated several times over, might have accomplished the mighty work, which we have imputed to them in Vermont, of ploughing out at length her deepest valleys.

That the region around these summit level gorges has been deeply under water, is manifest from the fact already mentioned, that almost always we find accumulations of water-worn materials near each end, sometimes one hundred feet high, as at Willoughby. Other considerations show the water to have been much deeper. The drainage of such an ocean might, in the manner above supposed, have tended to produce the conformation of surface which we now witness, and we know of no other mode in which it could be done.

This hypothesis does not necessarily require a summit level gorge. It may be applied to the excavation of any continuous valley. Several such valleys exist in Vermont, and the adjacent portions of New Hampshire, whose erosion we can explain in no other way. To some of them we have been able to give so slight attention that perhaps we are unwise to name them. But as we profess to give only hints on this subject, which seems hitherto scarcely to have engaged the attention of geologists, we shall name those valleys which, so far as we can judge, have been produced mainly by the agencies under consideration.

1. From the mouth of Mulhegan River in Essex county, through Island Pond and Memphremagog.—The height of the summit level, at Island Pond, on this route, is 1182 feet above the ocean, but not half as much above Connecticut River, and we can hardly doubt that oceanic and perhaps fluviatile currents once flowed through it.

2. From Island Pond to the Connecticut River at Barnet, mostly down the valley of the Passumpsic.—Of this we know but little.

3. A valley along the Passumpsic Railroad, from Burke through Barton; a little beyond which, it enters the valley already described from Willoughby Lake to Memphremagog.

4. A valley passing southerly from Memphremagog, up Black River, through Coventry, Irasburgh, Albany, Craftsbury and Hardwick, passing to the La Moille, down Alden Brook. A survey of this route superintended by De Witt Clinton, for a canal, gives the following elevations above Lake Champlain.

Albany,	687 + 90 = 777 above the ocean.
First Elligo Pond,	710 + 90 = 800 above the ocean.
Summit Level,	713 + 90 = 803 above the ocean.
Little Elligo Pond,	696 + 90 = 786 above the ocean.
Sinclair's Rapids, La Moille, River in Hardwick,	713 + 90 = 803 above the ocean.

Memphremagog, according to Thompson, is 695 feet above the ocean. A rise of 100 feet, it would seem, would throw its waters into the La Moille. It certainly did once stand, and for a long time, at an elevation greater than this, as the terraces on its borders prove. All the old valleys above indicated must then have been filled, as must also the whole valley of the Connecticut, and of Champlain, and the Hudson, as well as a multitude of inosculating valleys among the hills. So that at that time the whole country between Connecticut and Hudson Rivers, must have been a lake full of islands, somewhat like Winnipisiogee in New Hampshire at present.

5. From Johnson village on the La Moille, to the Missisco, down Sheldon Creek. We have been credibly informed that a rise of little over 50 feet, in either of these rivers, would carry its waters into the other.

6. From Lancaster, in New Hampshire, to the mouth of the lower Amonoosuc. Without much doubt this was an ancient bed of the Connecticut. The summit level is at Whitefield.

7. Two cases in Huntington. These also have been described in the history of Terraces.

8. The passage of the Winooski through the Green Mountains. After following this range from the southwestern part of Massachusetts, or even further south, for 140 or 150 miles, and finding it unbreached any where, it is truly surprising to see the Winooski cutting a nearly straight course across it to the very base of the mountains, and retaining but slight evidence in the shape of falls, how the work was done. On the sides of the gorge we find the rocks standing almost upon their edges, the layers passing across the river, and bearing evidence of erosion, not of dislocation; so that no "great convulsion of nature" can here be evoked to explain the phenomena. But we are forced to the conclusion that this gorge has been worn away by the slow action of water. But how enormous the work and into what distant ages of the past must we look for its commencement. Imagination can picture a time when the giant crest of the Green Mountains stretched unbroken almost to Canada, with only here and there a depression. The ocean too, stood almost as high, but its waves broke over one of those depressions, and began a work, which having been unceasingly carried forward, either by the ocean or by rivers, through countless ages, is well nigh completion, and amazes us by its magnitude. Probably since the settlement of Vermont by the white man, the Winooski has not lowered its bed (except perhaps at some cataracts), a single inch. Yet this mountain, say from a height of 2,000 feet, has been cut down to its base by the same agency that has done the whole work, although now showing itself probably in its least effective form; for we are disposed to refer the lion's share of erosions to the ocean.

Nor has this great work been without design; but, like all other works of the Creator, we can see definite objects accomplished by it. And when we see a railroad following a valley of erosion from the mouth of White River to Burlington, across the whole central part of the State, and passing by its metropolis, do we not see one of those objects? For without such erosions, such communication would hardly have been possible. And though the construction of a railroad, even through such a valley, be a great labor, yet just think how vastly greater has been the previous work performed by nature, and man's part sinks into comparative insignificance.

The same reasoning as to providential design applies to other railroad routes in the State; and also to some valleys equally well adapted for steam communication. And if it be said that these last cases show that there has been no special design in their erosion, we reply that railroads are not the only means of inter-communication facilitated by them: but we ask the objector to wait a hundred years to see how many more of these valleys will echo the steam whistle before that time,—for some of us well remember the day, and that too since we began to look at its geology, when it had not been sounded within the limits of Vermont.

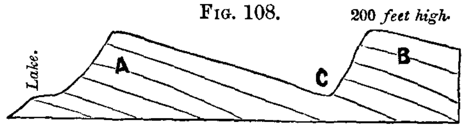
9. The passage of La Moille River through the Green Mountains. The general character of this valley corresponds so well to that of the Winooski, that the same description and theories and inferences will answer for both.

AMOUNT OF EROSIONS.

Have we not now presented facts enough to justify the inference that all the valleys of the mountainous parts of Vermont have been the result of erosion, excepting, perhaps, the broad Champlain Valley, and possibly the general depression known as the Connecticut Valley? In other words, the present contour of the surface, with these exceptions, has been the result of denudation. That the original surface, before denudation began, may have been very irregular from original structure, upheaval and plication, we do not doubt; but we think that subsequent erosion, with the exceptions named, may have entirely obliterated all the original forms of the surface, except that these original forms gave the directions, which they have taken, to the denuding agents. If, as we have endeavored to show, we must admit some of the deepest valleys of the State to have been due to erosion, there is no difficulty in admitting it of all; but there is a difficulty in admitting it of one or two and excluding it from the rest; because, if sufficient for one or two it is sufficient for all.

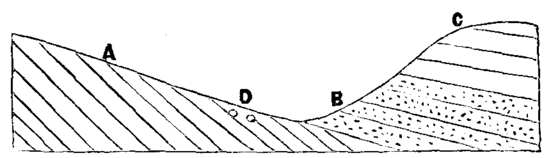
How far erosion was concerned in forming the Champlain Valley, we cannot say. But we have evidence that it had a share in the work. This is obvious around Whitehall. The rocky ragged hills lying a little north of the town, bear decided marks of denudation in their outline, as the subjoined sketch (Fig. 108) shows. It was taken on the north of Poultney River, just within the limits of Vermont, and shows clearly the denudation of the calciferous sandstone, B, leaving a harder outline, A, of Potsdam sandstone, the river, C, running between the bluffs.

Fig. 108. 200 *feet high.*



The junction between the Potsdam sandstone, B, and gneiss, A, (Fig. 109), occurs in the village of Whitehall, which lies in a valley between the two rocks. That erosion has taken place here, and that by fluviatile action, is obvious from the fact that near the junction of the two rocks, probably in the gneiss, pot-holes, D, are found. They are from 6 to 8 feet in diameter, and 60 to 70 feet above the lake, as is represented on the subjoined section (Fig. 109), which crosses the valley through the village. C represents the position of the calciferous sandrock.

Fig. 109.



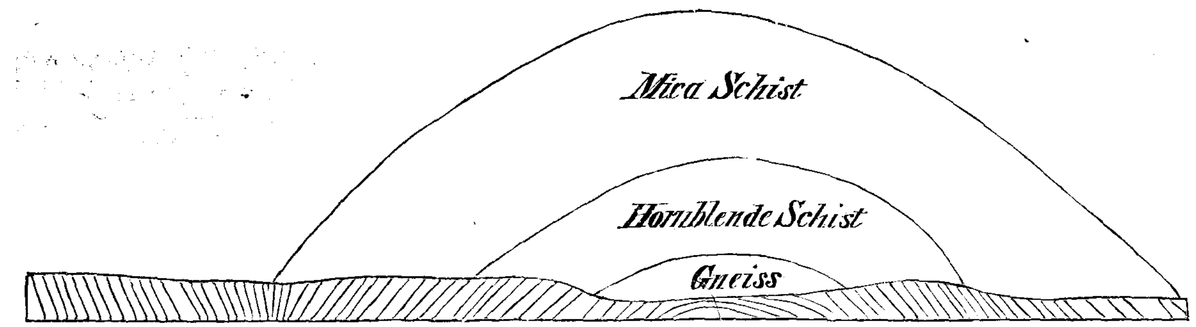
These facts indicate a large amount of erosion in the Champlain Valley, but will not justify the inference that the whole of it was worn out. We rather incline to the opinion that we may have here some indication of an original depression in the strata, as we probably have in the valley of the St. Lawrence, of which this is the southerly prolongation. But it does not seem to us that we press the facts beyond their natural bearing, when we maintain that probably in all the mountainous parts of the State the valleys are those of erosion. It is an immense and startling conclusion, and until we had carefully scanned the facts, we shrunk from it, but do not now see how to avoid it.

DENUDED STRATA.

But we have other arguments to present on the subject of erosion in Vermont, which go to show that its amount has been far greater than we have yet stated it. The evidence that has been most relied on to prove denudation, is derived from the amount of rock that has disappeared from the tops of anticlinals. It is argued that stratified rocks must once have been continuous, and, where we find large gaps in them, the amount of matter necessary to fill them up is a measure of the erosion. If they have been folded up, as they must be to form an anticlinal, and the top of the fold is gone, we infer that it has been worn away. To take an example in Vermont: The sketch below (Fig. 110) is taken from Section II, and shows the rocks in West Brattleboro, towards Marlboro. There we have on both sides of the anticlinal gneissoid mica schist in the center, next hornblende schist, and beyond this, mica schist. Now the supposition is that those rocks were once united at the top, as represented by the curved lines. And if we could measure the exact

thickness of the different strata and get their true dip, we might by protraction find out what thickness had disappeared from the present surface.

Fig. 110.



One of our number (C. H. H.) has attempted this, as well as the limited time at his command would permit, with the following results:

Thickness	of the Gneiss that has disappeared,	951 feet.
do.	of the Hornblende Schist, . .	2640 feet.
do.	of the Mica Schist, ...	3933 feet.
	Total thickness,	7524 feet,

or not far from a mile and a half.

On Section I, this same anticlinal probably shows itself; at least the hornblende schist appears; but there the difficulties are still greater as to measurement. Still further to the southwest, however, at Shelburne Falls, in Massachusetts, a few miles south of the Vermont line, the same anticlinal probably is brought to light more satisfactorily, as is shown in the adjoining section (Fig. 110 *bis.*) C. H. H. devoted more time to this case, before commencing the Vermont Survey, and found that nearly 10,000 feet have disappeared from the valley of Shelburne Falls!

Fig. 110 (*bis.*)

In South Wales the erosion was as much as 10,000 feet, according to Prof. Ramsey, and his sober conviction was, that more land has disappeared from the island than now remains above the waters. We do not doubt that the same is true of New England. But it demands much time to work out the problem fully, among our metamorphic rocks. It is certainly a grand subject, and its solution would richly repay long and laborious research. An inspection of our sections will show many places where anticlinals exist, of such a character as to afford a fair opportunity for measurement, though we think it probable that the disturbed fossiliferous rocks of our country present a more promising field.

PROOF FROM THE UNSTRATIFIED ROCKS.

Another evidence of erosion, and a measure of it, is derived from the unstratified rocks. Admitting, as most geolgists do, that they have been once in a melted state, it is obvious that while in that condition they would flow into the lowest places, and could not be made to stand up in walls or peaks, unless surrounded and supported by other rocks. If, therefore, we find mountains cut through by dikes of trap or porphyry, or veins of syenite and granite, we may be sure that other rocks must have surrounded and covered the fissures as high as we now find them filled, otherwise the fused matter would have all run out of the fissures. So if we find any of these rocks shooting up as naked ridges or peaks, we know that when first melted or protruded they must have been buttressed up by stratified deposits, until they were hardened. Nay, there is so much evidence that granite was formed very deep in the earth and under powerful pressure, that, as a late able geologist says, "we may feel sure that at the time of its consolidation, it was covered with a thickness of at least several thousand feet of other rock, and that this thickness has been removed by the gradual action of erosion by moving water." (*Juke's Manual*, p. 273.) We must, therefore, add several thousand feet to the height above the present surface of the most elevated ridges or peaks of granite, in order to ascertain the amount of erosion; and we ought to remember too, that the granite also has been cut down not a little, after its cap rock had been abraded.

With such rules for our guide, let us now turn to the unstratified rocks of Vermont, to see what lesson they teach us. Generally the dikes of trap do not occur at a great height. We think those at Mt. Holly, about 1400 feet above the ocean, or 1300 above Champlain, are the highest, unless it be some small ones on Danby Mountain. But to prevent the melted matter from flowing out of these, would require buttresses of stratified rocks nearly as high as any part of the Green Mountains, and consequently high enough to fill up all the present valleys of the State.

Prof. O. P. Hubbard, several years ago, presented an able paper in the American Journal of Science on trap dikes in New Hampshire, as an evidence and measure of erosion. (*Vol. IX, N. Series*, p. 158.) He there states that he found a trap dike cutting through Mt. Pleasant, one of the White Mountain group, at the height of 4500 feet. This would require a cap of stratified rock as high nearly as any part of the White Mountains; and hence Prof. Hubbard infers, with great reason, that "the deepest valleys" of New Hampshire "are but valleys of erosion."

We reach a similar conclusion by an examination of the granitic and syenitic peaks of Vermont. We can hardly doubt that most of these have resulted from the metamorphosis of other rocks and have not been thrust up from the interior of the earth into cracks and through the strata. But in all cases we cannot doubt that such metamorphoses would bring the materials into a melted state, enough certainly to cause the mass to flow. In some cases we have evidence of such a condition; and since these embrace the highest granitic peak in the State, we pass by all other examples and let this stand *instar omnium*.

Throughout the whole length of the Connecticut valley, we find occasional peaks of granite and syenite which have indurated the adjoining rocks, and sent veins into them,

and have veins also cutting through their own masses, so as only a fused rock could do. Near the south part of the State we have Black Mountain, which, however, is not very high. But Ascutney shoots up 3320 feet above the ocean, and about 3000 feet above the river. Further north are many other deposits of granite, increasing in quantity towards the northeast part of the State. But we believe (although we have not been able to measure the heights of some of them in theunsettled regions of Essex county) that Ascutney peers above all the rest, and we will let this stand as a representative of the whole.

The predominant rock in this mountain is syenite, with very little hornblende, however, and hence it often passes into a highly feldspathic granite, and sometimes into porphyry, with a crystalline and not a compact base. Sometimes we find large and irregular veins of granite, penetrating the syenite in such a manner that large surfaces look like breccia. Indeed, we often see concretionary masses, only a few inches across, scattered through the granite. Such facts can be explained only by fusion.

The strata all around the mountain have a strike somewhat east of north, and a large easterly dip, and they do not seem to have been much disturbed by the elevation of the mountain; though on the west side we found them sometimes horizontal, and sometimes perpendicular, where they are in immediate contact with the granite; and all around the mountain, even at considerable distance, they are a good deal indurated. At first view it seems as if the mountain was a huge bed in mica schist and gneiss; but we think that it does in fact cut across the strata, nearly at right angles; having, however, disturbed them so little that they abut against the north and south sides with almost unaltered dip and strike. It may be difficult to conceive how such a mass of melted rocks, several miles in diameter, should be produced among the strata without great disturbance. But the old and common idea that granite usually forms the axis of a mountain, and that its protrusion has thrown up the strata on opposite sides so that they dip in contrary directions, is beginning to be regarded as a hasty generalization. Our experience, we confess, has scarcely made us acquainted with a single case of this kind. But everywhere the granite seems to have merely partaken of the general elevatory movement, and not to have been itself the cause of it; so that often, as at Ascutney and many other places in Vermont, the stratified rocks appear to pass under the granite, judging from their dip at a short distance. But wherever we have seen the junction of the two rocks on the west side of Ascutney, we find so much of disturbance and change of dip for a short distance, as to doubt whether the stratified do pass under the unstratified, and the same is true in the Stamford and Pownal granite.

Where granite occurs in interstratified beds in stratified rocks, we may generally regard it as simply a metamorphosis of those rocks. But when the metamorphosis is so complete as not only to obliterate every trace of stratification, but also to send the melted matter into fissures so as to form veins, we may be sure that the heat was great enough to produce entire fusion, and therefore such a rock as we might found an argument upon. Now we have ascertained the curious and interesting fact, that at least a part, and perhaps all of Ascutney, was formed by the melting down of a coarse breccia, no longer found in the region, save the small portion that remains unmelted as a coating of the granite of Little Ascutney, without an intervening seam. The facts on the subject will be detailed in another part of this Report.

From all these facts we cannot doubt that Ascutney has been in a melted state, so as to require the stratified rocks to rise around and above it to prevent its flowing outward. And if they probably extended 2000 or 3000 feet above its present top, as we do not doubt, then the amount of erosion at Windsor has been as much as 6000 feet, or a mile and a quarter! And by parity of reason, probably it has been as great all along the Connecticut valley; so that originally the surface there was as high as Mt. Washington.

The vastness of such a denudation makes us almost shrink from this conclusion. Yet we see that it is sustained by three independent sources of evidence, and does not exceed the amount that has been swept from other lands. Yet how vast the time requisite to such a work by any agencies now in operation! Imagination can hardly grasp the mighty periods that have passed by since it began.

A few years ago it would have been necessary, to prevent unreasonable imputations, when thus assigning an age to the world so vast, to have stated our conviction that such facts and conclusions are not discrepant to the Mosaic History of creation. But the great age of the world is now so generally admitted by theologians, and that Moses does not fix the time when the world was created, but only says that it was *in the beginning*, that we hardly need say that, between the scriptures and geology on this or any other point, there is, in our view, not only no collision but harmony and mutual corroboration.

II. TERTIARY STRATA.

We have occupied a good deal of space with the Surface Geology of the State. But Vermont is particularly rich in phenomena of this sort; and we fancy that we have been able to present more that is new, than we shall be in any subsequent part of our report. We now advance to some deposits which we venture to refer to the Tertiary Period, although not with strong confidence, and with the knowledge that some able geologists hesitate to admit our conclusions.

A few years since the idea of finding tertiary strata in Vermont would have been regarded as absurd. But some facts, which came accidentally under our notice when engaged in a survey of the Surface Geology of Massachusetts, led to the conclusion that a newer tertiary formation existed not only in Vermont, but extended, at intervals, through nearly the whole United States, along the foot of the Appalachian Mountains; and although the evidence was found in Vermont, yet its importance in relation to certain ore beds in western Massachusetts led us to embrace a description of the Vermont deposit, in a Report to the Government of Massachusetts. It was an account of a deposit at Brandon, and in looking it over we do not see that any important changes are necessary to express our present views, except to add to the number of species of fruits and seeds, and to notice some objections that have been made to the tertiary character of the strata. We beg leave, therefore, to make it a part of our present Report.

FOSSIL FRUITS.

In the autumn of 1851, Prof. Shedd, of Burlington, presented me with a few specimens of beautifully preserved fruits from Brandon, Vermont. They were converted into brown coal, and retained exactly their original shape and markings. Early in the spring of 1852, I visited Brandon, and found that the fruits were obtained from a bed of brown coal connected with the white clays and brown hematite of that place. I perceived at once that an interesting field was open before me; and ever since I have been endeavoring to explore it. Great difficulties presented themselves, and I have resorted to several gentlemen, both in this country and in Europe, for aid. Their opinion has yet been obtained only in part. But there are several points, of much interest to American geology, cleared up by what I have already ascertained. I have concluded, therefore, to give a brief account of this case, hoping hereafter to make additions to it.

I would here ackowledge my deep indebtedness to John Howe, jr., Esq., the Agent of the Brandon Iron and Car-Wheel Company, who are the proprietors of this deposit of iron, clay and brown coal. Not only did he do all in his power to aid my investigations upon the spot last spring; but since then he has sent me, free of expense, numerous specimens of the fruits and the coal; especially at one time two barrels of the coal containing the fruits, and at another time a gigantic mass of lignite,—the trunk of a large tree, in fact, which is now deposited in the cabinet of Amherst College.

I shall first give a description of the topography and geological associations of this carbonaceous deposit; next an account of the lignites and fossil fruits; and finally deduce from the facts some geological inferences of importance.

II. *Topography and Geological Associations.*

Geologists are aware that along the west base of the Green and Hoosac Mountains, from Canada to New York, occur numerous beds of brown compact and fibrous hematite iron ore. That in Brandon lies between two and three miles east of the village. Passing easterly from the village, the surface rises slightly, and exhibits clay, drift and limestone rock in place. According to my measurements with the Aneroid barometer, Brandon village is 465 feet above the ocean, and the iron mine 520 feet above the same. A short distance east of the mine, the Green Mountains rise rapidly.

At this spot we find the following varieties of substances in juxtaposition:

1. Beautiful kaolin and clays, colored yellow by ocher, rose-color by manganese, (?) and dark by carbon.
2. Brown hematite and yellow ochre.
3. Ores of manganese.
4. Brown coal.
5. Beds of gravel connected with the clays.
6. Drift, overlying the whole.
7. Yellowish limestone, underlying the whole.

The position of the clays it is difficult to determine exactly, as there seems to have been a good deal of disturbance of the strata, perhaps only the result of slides. The iron is generally found beneath the clay, as is also the manganese. The coal, in a few places, shows itself at the surface. In one spot a shaft has been carried through it only a few feet below the surface, and the same has been done to the same bed, nearly 100 feet below the surface. In both places it is about twenty feet thick. I found it to be the conviction of the miners, that this mass of coal forms a square column of that thickness, descending almost perpendicularly into the earth, in the midst of the clay. My own impression was, that it is a portion of an extensive bed, having a dip very large towards the northwest; perhaps separated from other portions of the bed by some disturbance of the strata. But I found great difficulty in tracing out its exact position.

It ought to be mentioned that no unstratified or igneous rocks are known to exist in the vicinity of these deposits; nor do they exhibit any marks of the metamorphic action of heat.

II. *Coal, Lignite, and Fossil Fruits.*

The greater part of the carbon of this deposit is in a condition intermediate between that of peat and bituminous coal. It is of a deep brown color, and nearly every trace of organic structure, save in the lignite and the fruits, is obliterated. Disseminated through it are numerous angular grains, mostly of white quartz, rarely exceeding a pea in size. It burns with great facility with a moderate draught, and emits a bright yellow flame, but without bituminous odor. After the flame has subsided, the ignited coals gradually comsume away, leaving, of course, a quantity of ashes. It is employed to great advantage in driving the steam engine at the works; and I should think it might be used advantageously for fuel in a region where wood is scarce, which is not the case at Brandon.

Interspersed through the carbonaceous mass above described, occur numerous masses of lignite. In all cases which have fallen under my observation they are broken portions of the stems or branches of shrubs and trees, varying in size from that of a few lines to a foot and a half in diameter. They all appear to me to have been drift wood. The largest mass which I have seen, and to which I have already referred, as sent me by Mr. Howe, resembles exceedingly a battered piece of flood-wood; which led Mr. Howe humorously to inscribe upon the box in which it was sent, *"A piece of flood-wood from Noah's Ark."*

This lignite, in all cases, retains and exhibits, upon a fresh fracture, its organic structure. Yet generally it is quite brittle, and when broken across the fibers, it has the aspect of very compact coal, which admits of a good polish. In some specimens the original toughness of the wood is not quite lost, and the aspect of the wood remains.

The large mass of which I have already spoken, as now in the cabinet of Amherst College, is four feet long and sixteen inches in its largest diameter. It is considerably flattened, but seems to have been so originally. In the peaty matter that adheres to it I noticed several specimens of fruit, and more than one species.

With perhaps one or two exceptions, all the lignite of this deposit belongs to the exogenous or dicotyledonous class of plants. In general, the texture is close, and some of the wood is very fine grained and heavy. The bark is often quite distinct. I have been inclined to refer some of the wood to the maple; perhaps some of it is coniferous; but my microscopic examinations on this point have not been as satisfactory as I could wish. I do not think much of the wood belongs to the pine tribe now common in this latitude. I have placed specimens in the hands of several distinguished vegetable physiologists, and had hoped ere this to learn their opinion; but they have not yet given it.

The fruits and seeds of this deposit are the most interesting of the relics found in it. But they are even more perplexing than the lignite. As yet, I hardly dare venture to refer any of them to living or fossil genera known to me. I shall, therefore, merely present figures of the principal distinct forms which I have obtained, and leave a minute description to some future occasion.

Figs. 111, 112 and 113 exhibit the most common fruit, always thus apparently flattened, with two valves generally dehiscent. These valves are made up of fibrous matter, the fibers arranged perpendicular to the

Figs. 111 & 112.

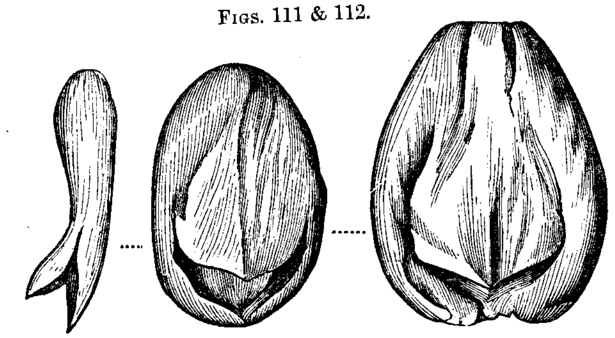
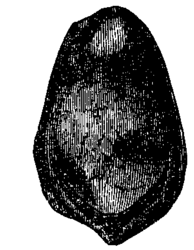


Fig. 113.



surface of the valve. The seed is always wanting; but the thin membranous integument once inclosing the seed, generally remains. The point by which they were attached probably to a capsule is very indistinct. These fruits are five times more numerous than any others.

Fig. 114.

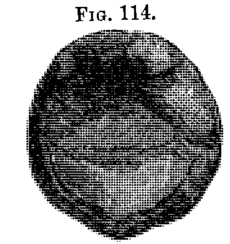


Fig. 115.

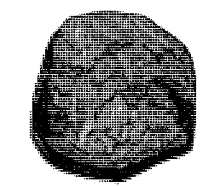


Fig. 116.

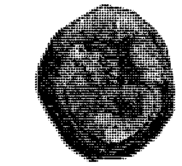
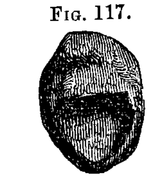


Fig. 117.



Figs. 114, 115, 116 and 117 are two-valved, and more rounded than those just described, but they may be only varieties of the same species.

Fig. 118 is three-valved; two of which are much the most distinct. It is also much more acuminate than the preceding. I have found not more than two or three specimens.

Fig. 118.

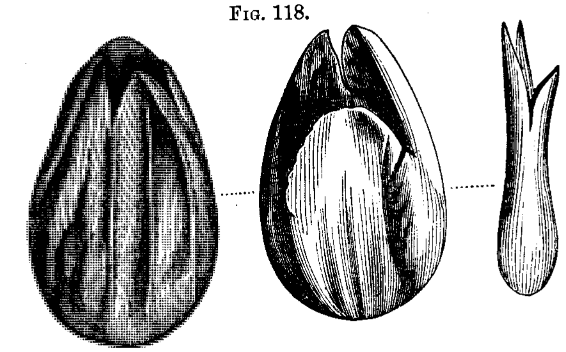


Fig. 119.

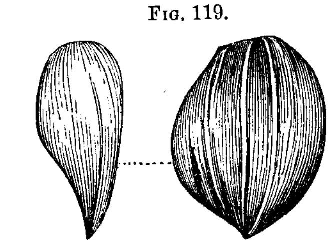


Fig. 119 shows a three-valved elongated fruit, with strong ridges on the valves. It tapers very much towards the apex. It is indehiscent.

Fig. 120 is more or less three-sided and short, the one side nearly flat, but the ridge on the other side very prominent. Valves closed—perhaps three.

Fig. 121 is ridged and more or less flattened, resembling one or two species of walnut, but the covering is fibrous, as in the species first described.

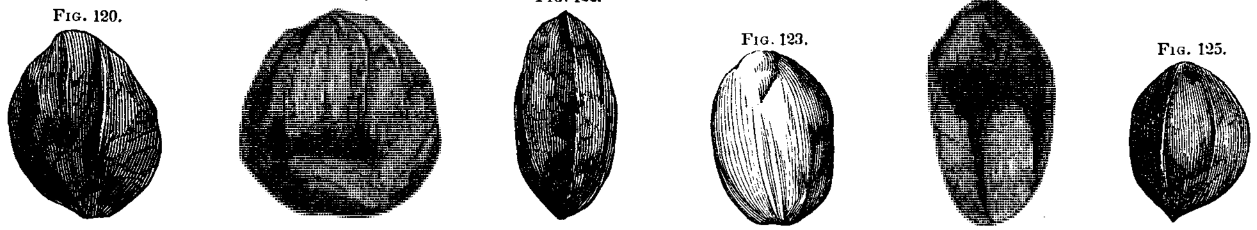


Fig. 120. Fig. 121. Fig. 122. Fig. 123. Fig. 124. Fig. 125.

Fig. 122 differs from the last apparently only in its elongated form, which is that of a large raisin.

Figs. 123, 124 and 125 are very similar to Fig. 121 ; but 124 and 125 are very thin in their lower part (that part opposite the stem), and 125 is also more or less four-sided.

In Figs. 126, 127 and 128, the fruit is distinctly triangular, and the valves are three. Fig. 126 exceedingly resembles a large beechnut. Others, as Fig. 128, look like the Brazil nut (*Bertholletia excelsa.*) The outside is rough and somewhat ridged lengthwise. Only a few have been found. In all the fruits thus far, the valves are composed of fibrous materials arranged crosswise.

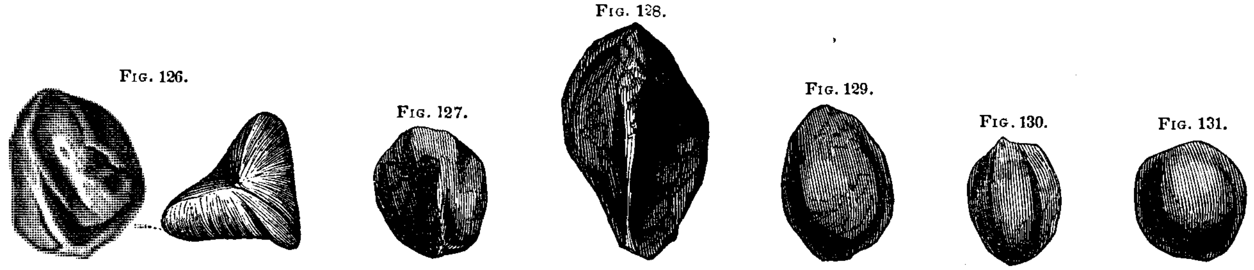


Fig. 126. Fig. 127. Fig. 128. Fig. 129. Fig. 130. Fig. 131.

Fig. 129 is a prolate spheroid, with six valves corresponding to the carpels of the capsule. It is quite rugose.

In Fig. 130, similar to 129, the septa or divisions of the six valves are quite prominent, and the sides are smooth.

Fig. 131 is spherical and smooth, with six valves, and different from the preceding.

In Fig. 132, which is spherical and rugose, the valves are seven,—a beautiful fruit, having the aspect of one or two species of walnut, but it contains no meat. It was probably a berry, for on breaking it, it appears nearly homogeneous throughout, and the integument is thin. Yet the valves are quite distinct, though indehiscent. In appearance, size, and texture, it resembles a nutmeg.

Fig. 133, which is slightly prolate, has seven valves, whose sutures form grooves rather than ridges. It is smoother than the last.

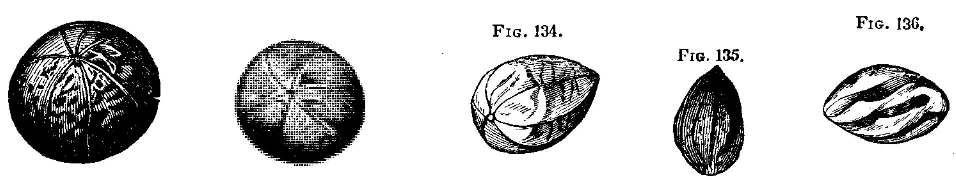


Fig. 132. Fig. 133. Fig. 134. Fig. 135. Fig. 136.

Figs. 134 and 135 are elongated and tapering towards the lower end, opposite the place of attachment. The seven ridges are quite prominent.

Fig. 136 has seven valves, and the ridges between them are so prominent that the spaces between them appear like deep furrows, and the ridges seem to run somewhat obliquely across the fruit.

Figs. 137 and 138 are more nearly spherical than the two preceding, and the seven ridges are less prominent.

Figs. 139 and 140 are nearly spherical and nearly smooth, with eight valves. Fig. 140 is somewhat elongated and one-sided ; that is, the place for the stem and the apex are not exactly opposite.

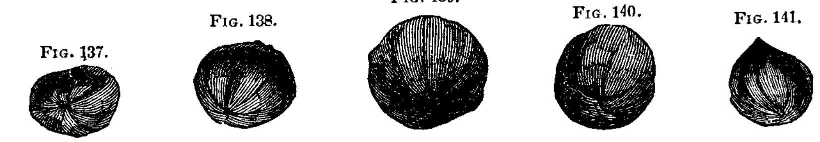


Fig. 137. Fig. 138. Fig. 139. Fig. 140. Fig. 141.

In Fig. 141 the ridges, which are eight, are more distinct than in the two last, and so is the apex. It is a smaller fruit.

From Fig. 129 to 141, inclusive, the fruits retain the exact form and plumpness which they had when they grew, unless sometimes a little flattened. Their carbonization does not seem to have produced a shrinkage. They were probably berries, yet I cannot discover seed, nor much evidence of cells.

Fig. 142 is bean-like, showing a point of attachment near one end, and a single furrow along the back. Fig. 143 is probably the same, though smoother. In these no valves are perceptible.

Figs. 144 and 145 show one half of bean or some other fruit, with a thick rind or shell.

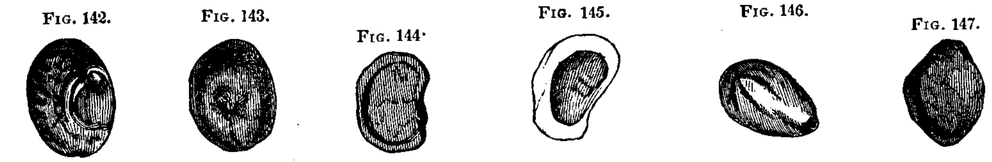


Fig. 142. Fig. 143. Fig. 144. Fig. 145. Fig. 146. Fig. 147.

In Fig. 146 we have a smooth pear-shaped seed, with a stem at the small end. Fig. 147 is probably the same, though not as distinct.

Fig. 148 is much like the two last, except in being much smaller and broader at the base.

Fig. 149 is a small smooth ovoid bean, with a hilum or ridge by which it was attached.

Fig. 150 appear like small smooth peas, with a distinct hilum.

Fig. 151 shows but imperfectly a small delicate pear-shaped hollow seed, with a hilum near the apex. Externally it is covered with delicate slightly flexuous ridges and correspondent grooves. The shell is very thin, but hard. This is not very uncommon.

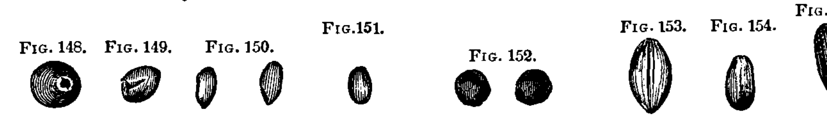


Fig. 148. Fig. 149. Fig. 150. Fig. 151. Fig. 152. Fig. 153. Fig. 154. Fig. 155.

Fig. 152 exhibits a spherical fruit about the size of a small pea. It was not probably leguminous, but was attached by a stem.

Figs. 153 and 154 show elongated ridged and flattened fruit, probably with valves.

In Fig. 155 we have a cylindrical elongated ridged fruit, probably with valves.

The four last specimens described are quite rare, and enough have not been found for dissection.

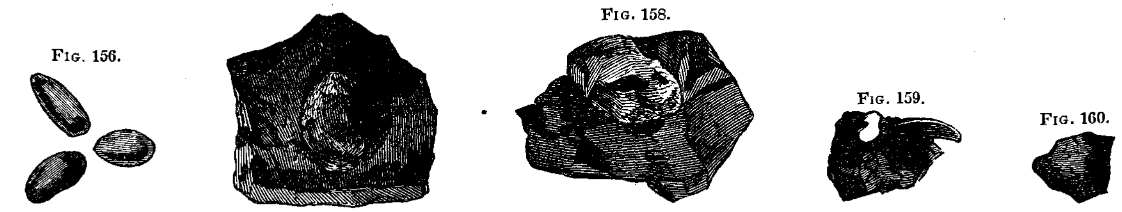


Fig. 156. Fig. 157. Fig. 158. Fig. 159. Fig. 160.

Fig. 156 shows an elongated, often flattened, and partly hollow berry. It is generally smooth, but sometimes shows a thin epicarp, somewhat striated, which doubtless was always present. The outer coat of the seed is thick and hard. The nucleus sometimes remains, but is dried up and no trace of organization left. This species very much resembles, and so far as I can judge by a comparison of specimens, is identical with the Carpolithus minutulus of Bronn's Lethea from the Brown Coal of Salzhausen. This fruit is one of the most common at Brandon.

Figs. 157 and 158 show the wrinkled skin of a fruit of about the size and having the aspect of a small raisin, except that the color is lighter; color sometimes almost white. This skin still retains its elasticity, and is not changed to coal. The pulp still remains without much appearance of organization.

Figs. 159 and 160 exhibit fragments of the hard external envelope of some seeds—probably of some that have been described.

In the above list we have at least twenty-three distinct species of fruits and seeds; namely, Figs. 111, 118, 119, 121, 123, 129, 131, 132, 133, 134, 136, 137, 139, 141, 142, 146, 149, 150, 151, 152, 153, 156 and 157. Doubtless an eye familiar with fossil fruits would distinguish more.

The only other fossil fruits that I have known to be found in the newer formation of our country, are a few from the tertiary strata at Richmond, Va. In respect to these, Prof. Jeffries Wyman has kindly furnished me with the following description:

"In my examination at Richmond, I have frequently found lignite, and occasionally fruits; but as I was more anxious for bones, I gave them but little attention. I have indentified a species of Carya (walnut) which was so pronounced by Mr. Teschemacher, Prof. Agassiz, and Dr. Gray. I have also found one species of pine cone, in company with pine lignite. The latter was interesting, as having changed, while lying on my table, from the condition of rotten wood, soft enough to yield to the tip of the finger, into lignite of the usual hardness and having the coal-like fracture. This, however, is no uncommon occurrence, and is said to be well known to geologists. The piece of wood just referred to had been bored by the Teredo.

"The above are the only instances about which I would speak with any confidence. I have also, from the same locality, a large mass of fossil resin. The vegetable fossils there found, with the teeth of Phyllodus, Cetacea, reptiles, sharks, &c., show a close resemblance of the Richmond formations to the London clay. I have in preparation a short notice in which the animal fossils of the two are to be compared."

CONCLUSIONS.

Although the specific characters of the Brandon fossils are thus imperfectly known, the facts detailed will warrant several inferences of importance in American geology.

I. *The Brandon Deposit belongs to a tertiary formation.* The following are the proofs:

1. It lies below the drift; and, for the most part, is not consolidated. Its position as to the drift, is seen at the openings made near the carbonaceous deposit; and the degree of induration—or rather, in general, the want of induration—corresponds to that of most tertiary deposits.

2. It contains all the important varieties of rock found in tertiary deposits. We have here white and variegated clays—water-worn beds of sand and gravel, beds of carbonaceous matter not bituminous, and deposits of iron and manganese.

II. *The carbonaceous matter in this deposit is strikingly analogous to that of the brown coal formation in Europe.*

1. The lignite has the deep brown color and coal-like fracture of the brown coal deposits that have not been affected by the proximity of igneous rocks, as is the case at Meisner in Hesse. Yet the woody texture usually remains distinct.

2. While this coal is distinguished from peat by burning with a bright flame, it does not give off a bituminous odor, and thus it differs from bituminous coal.

3. The degree of carbonization of the fruits corresponds to that in the brown coal formation, as a comparison of specimens shows.

4. The sand and clays associated with the brown coal of the Rhine Valley, occur also at Brandon.

III. *The fruits and lignite of this deposit appear to have been transported by water, and probably the accumulation took place in an ancient estuary.*

1. No example has occurred in which these fruits have been found in clusters, or attached to the branches on which they grew, or to their envelopes. Nor have I found more than a single imperfect example of a leaf.

2. The lignite is in broken and usually bruised masses, as if battered by contact with one another when floating down stream.

2. The numerous places in other parts of the United States where an analogous deposit occurs,—as will be shown below,—render it probable that this was formed in an ocean, rather than a lake.

IV. *The Brandon Deposit is the type of a tertiary formation hitherto unrecognized as such, extending from Canada to Alabama.*

This formation is identified by the following characters:

1. The most prominent and well known substance in this formation, on account of its economical importance, is brown hematite. In the geological surveys of Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania and North and South Carolina, this ore is described by Adams, Shepard, Percival, Mather, Henry D. and Wm. B. Rogers, Olmsted and Tuomey. Throughout this whole distance of 1,200 miles there is a striking resemblance in the character of the ore. It is compact, fibrous and stalactical; and much of it is in a state of ocher.

2. It is always more or less enveloped in clay of various colors.

3. It is almost invariably found lying upon, or near, a certain sort of limestone, or its associated and interstratified mica schist. This limestone is usually highly crystalline, and when disintegrated, it shows a large proportion of iron in its composition; and the general opinion of the geologists above named is, that the iron originated from it. I have, likewise, some reason to suppose that Foss' bed of hematite in Dover, N. Y., may once have constituted a bed in mica schist.

In all the Northern States, the beds of this ore occur along the western base of high mountains. And from the description of the gentlemen above named, I understand this to be the case in the Middle and Southern States. Prof. Henry D. Rogers imputes this fact to the southern direction of the currents in the great ocean by whose waters the iron and the clay were deposited, and to the greater depression of the valley on its south-eastern side. Prof. Rogers is the only geologist, I believe, who speaks decidedly of the deposition of this ore from the ocean. By this supposition, he comes so near representing this formation as tertiary, that it would have needed only a bed of carbonaceous matter, such as occurs at Brandon, to have brought him upon that ground. Not improbably, now that the Brandon bed is known, similar ones may be found associated with the ore at other localities: for, how long has it remained unnoticed at Brandon?

Thus does the discovery of the Brandon Brown Coal Deposit enable us to add to American Geology a tertiary formation nearly 1,200 miles long, which may appropriately be placed upon our maps.

V. *This Deposit probably belongs to the pliocene or newer tertiary.*

1. So far as we know, it lies immediately beneath the drift.

2. It is destitute of any consolidated beds, save the nodules of hematite; which is not true of any of our miocene or eocene deposits.

3. The brown coal of continental Europe, to which ours corresponds closely in appearance, belongs to the newer tertiary.

I confess that these arguments are not sufficient to remove all doubts from my mind as to the part of the tertiary group to which this formation should be referred. All geologists, however, I think, will say that it has marked peculiarities, which distinguish it from all the tertiary deposits of our country hitherto described; and we may, at least, say that the presumption is strongly in favor of its being pliocene. It is rather remarkable, if it was an oceanic deposit, that no marine remains have been found in it. I believe, however, that this is very much the case in Germany; though, unfortunately, the papers of Horner, Von Dechen and others, on the brown coal, are not within my reach.

I would add a few remarks of a practical character to the preceding account.

If the view taken in this paper be correct, we cannot expect that the beds of hematite ore extend into the solid rocks; although it may be, and if the ore was derived from these rocks we might expect that we should find veins and possibly beds of similar ore in the subjacent limestone and mica schist, as in fact they do occur sometimes, as detailed above. But the ore that is wrought, seems to have been derived mainly from the decomposition of the underlying rocks, through which it was disseminated, very likely in the form of a carbonate, and not an hydrated oxyd; and therefore, in its present form, it is a regenerated ore.

Again, this ore, according to these views, may be looked for anywhere along the western base of the Green and Hoosac Mountains, between the levels of the highest and lowest known beds.

And let me here suggest whether it would not often lead to important discoveries, if, between the levels above named, borings were made till the solid rock was reached. This would certainly be a cheap method of ascertaining the existence of the ore, and the thickness of the beds.

OTHER ANALOGOUS DEPOSITS IN VERMONT.

Wherever we have found brown hematite and manganese, or beds of ochre, or pipe clay, white, yellow or red, in connection with beds of coarse sand or gravel, all lying beneath the drift, and resting on the rocks beneath, we have regarded the deposit as an equivalent of that at Brandon just described, even though not more than one or two of the substances named be present. These deposits occur chiefly along the western ably not exceed the truth to represent a continuous narrow belt. North of Middlebury the localities are

base of the Green Mountains. From Stamford through Bennington, as far as Middlebury, it would probfew, perhaps from denudation. On the east side of the principal ridge of the Green Mountains, are also a few. We will give a list of the towns where some varieties of these substances have been found, attaching the height in feet above the ocean where we have ascertained it by the Aneroid Barometer. After giving the list we will notice any circumstances respecting some localities which we deem worthy of attention.

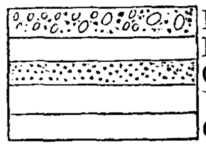
Stamford, 1140 feet above the ocean.
East Pownal, 1150.
Woodford, 720 to 1008.
East Bennington, 653 to 720.
West Bennington, 720.
East Arlington, 575.
Shaftsbury.
Sunderland.
Manchester.
East Dorset, 1116.
Mount Eolus, 1412.
West Dorset, about 1100.
South Wallingford, 729.
Clarendon.
Chittenden.
Rutland.
Pittsford, 433.
Brandon, 506.
Leicester.
Salisbury.
Middlebury.
Bristol.
Monkton.
Colchester.
Milton.
Swanton.

East side of the Green Mountains.

Waitsfield.
Reedsboro, Hartwellville, 1875.
Plymouth, Tyson's Furnace, 1168.

The difficulty of determining the order of arrangement of the different substances and their dip, has already been stated. At East Bennington the order is as follows (as given by C. H. Hitchcock.)

Fig. 161.



Drift.
Pipe clay with numerous stems of plants.
Gravel.
Yellow ochrous clay.
Clay with nodules of hematite and pyrolusite; depth not ascertained. Angular fragments of hyaline quartz and quartz crystals are common in the clay.

At Monkton the bed of white clay is 23 feet thick and overlies a bed of gravel. The hematite bed is half a mile distant.

At Colchester, two miles northeast of Mallett's Bay, is a bed of hematite; and bowlders of the same, weighing 100 pounds, have been found with ocher a considerable distance from the bed.

In Chittenden, according to Prof. Adams, the hematite, in a solid bed two or three yards in thickness, lies upon the limestone with the intervention only of a layer of ochre, one or two inches thick, and the ochres and clays above it.

In Wallingford, we understand Prof. Adams to say, that the clays and ochres underlie the ore.

In North Dorset is a dike three feet wide, in limestone, whose contents have an ochreous appearance, and are so soft as easily to yield to the knife. They are chiefly lithomarge, which is an hydrous silicate of alumina with but little iron. It is, evidently, a decomposed dike of porphyry, or porphyritic trap, for it still exhibits minute crystals of feldspar, which retain their white color, although thoroughly decomposed. The dike has been opened 150 feet, and it has been traced half a mile. The lithomarge is used for paints. It may have given rise to some ochre, but ought hardly to be regarded as a deposit of hematite.

In Chittenden, also, there is a vein of manganese, nearly two yards wide, in a loose arenaceous rock, which appears to have been once calcareous,— like the calciferous sandrock.

On the east side of the Green Mountains, only a few localities have yet been found of brown hematite, associated with manganese, white and colored clays, gravel, quartz rock and limestone. That in Plymouth is a very decided case, however. All these substances are here associated, and the formation is most decidedly the equivalent of those already described, along the western base of the Green Mountains. Most likely the quartz and limestone once extended over the mountain, and were subsequently denuded. As the limestone extends north into Sherburne, probably hematite may also be found there.

Whether the quartzose breccia in Hartwellville, near the crest of the Green Mountains in that place, should be reckoned among the hematite deposits already described, is doubtful. The cement is doubtless hematite; but there are no signs of limestone, or quartz, or of the white and variegated clays. The great height, also, above the ocean, seems to separate it by a wide interval from the other beds. And yet it must have resulted from the same agencies as the other hematite beds, but perhaps not at the same geological period.

The origin of these beds is a difficult subject for the geologist. We find them, almost without exception, associated with metamorphic limestone, quartz rock, which is perhaps metamorphosed sandstone, and with mica schist, which has also been metamorphosed. But from which of these rocks was the iron derived? For in general its present position is the result of the action of water, which has worn it off from the subjacent rocks, and re-deposited it in connection with clay, sand and gravel. In a few instances, however, we find it in the rocks. At west Stockbridge in Massachusetts, the bed of ore with interstratified clay has not lost the marks of original stratification. It seems to be merely a mass of metamorphosed mica schist, and in the northeastern part of Connecticut, as well as the eastern part of New York, in the same latitude, we have seen beds of hematite lying between strata of mica schist. (*See Final Report on the Geology of Massachusetts*, p. 584.)

To ascertain whether the iron did not result from the disintegration of the associated limestone, Mr. G. F. Barker was kind enough to furnish the following analysis of the limestone underlying the hematite of Brandon.

Carbonate of Lime, . . .	40.88
Carbonate of Magnesia, . . .	51.40
Carbonate of Iron, . . .	3.61
Quartz and other insoluble matter,	3.44
	99.39

East of the Brandon bed is a limestone used as a flux, that contains 10 per cent of iron. It is obvious then that the limestones may have furnished the whole or a part of the iron. But its occurrence in the limestone, and as beds in mica schist, leads rather to the conclusion that in part such may have been the origin of the hematite. Indeed, we are of the opinion that the ore was derived from both the rocks, and possibly, also, in some cases from the quartz rock. It is now well understood that the different species of iron ore undergo changes naturally in the earth from one into the other. Starting with carbonate of iron, it is changed into hematite hydrous and anhydrous; then into specular iron, then into the magnetic protoxyd. At the surface all the other ores of iron are apt to pass into hematite; and in the earth, below the influence of the atmosphere, into magnetic iron. (*See Bischof's Chemical and Physical Geology*, Vol. II, p. 53. Also *Lesley's Iron Manufacturer's Guide*, Chapter II, Part II.)

Now it is well known that all the species of iron ores above mentioned, and also the sulphuret, occur in the rocks that underlie the hematite, or are not far from it. The carbonate exists, as we have seen, in the limestone beneath the hematite beds, also in the mica and especially the talcose schists. Generally the specular and magnetic ores are found in schists that have undergone a more powerful metamorphic action than those underlying the hematites. The inference, therefore, is certainly fair, that whatever rock contains the carbonate of iron especially, and indeed any of the other species of iron, may prove a source of the brown hematite. In some instances, already mentioned, we find the exposed portion of the vein or bed transformed into hematite, but not denuded; yet in general the disintegrated portion has been more or less swept off by water and re-deposited. Hence we should say that no one rock, but all that contain other ores of iron, especially the carbonate, may have originated the hematite.

ARE THESE STRATA TERTIARY?

But have we sufficient evidence to refer this ore in its present position to the tertiary period? Certainly not those portions that have never been removed from their original and much earlier strata, where they have merely undergone disintegration and decomposition. But where the iron is associated and interstratified with layers of clay, sand and lignite, was the deposit made during the pliocene tertiary period? We have already presented a summary of the evidence to sustain the affirmative of this question. But in his recent able work, entitled *The Iron Manufacturers' Guide*, J. P. Lesley has controverted this opinion. He takes the ground that the beds "are the weathered or degraded outcrops of the silurian limestone on which they lie," and are sometimes connected with No. II, and sometimes with No. VI, of Rogers, which fact he thinks inconsistent with the idea that they are tertiary. But we do not see the force of this objection. For if these different formations, on whose edges or faces the hematite had been prepared by disintegration, were under the ocean, why might not its waters wear off and re-deposit these substances on different rocks during the same geological period, especially during their vertical movements? They might differ a good deal in age and still belong to the same geological period, none of which seem to have been stinted for time. As will be seen, we agree with Mr. Lesley that these deposits are "weathered and degraded outcrops" of other formations. But the question is, when were the materials worn off and re-deposited? All our experience shows them to be below the regular drift, and to rest on rocks which certainly are not newer than metamorphic Devonian strata. During which of the geological intervals in this wide gap were they deposited? They are not consolidated (save the iron to some extent), but correspond exactly in this respect to the tertiary strata. So they do as to the materials which constitute them. The white and variegated clays, as well as the sand and gravel, could not be distinguished by the eye from those which we see on the Isle of Wight and Martha's Vineyard. The white clay is not properly kaolin, resulting immediately from the decomposition of feldspar, but has been deposited by water, certainly in all those cases where it is interstratified with the other substances. If these deposits are any of them older than the tertiary,—say cretaceous, oolitic, triassic, or permian, why are they not consolidated, as in all other places? Why do they retain so exactly the lithological aspect of tertiary rocks, if of some other age? But it was the lignite and fossil fruits of Brandon that specially arrested our attention, as having exactly the aspect and degree of carbonization, which mark the tertiary coals of Germany and other countries, and which are found in no other formation. And as the coal in Brandon is connected with the iron, as well as the clays and gravel and manganese, if this be a tertiary deposit so is it reasonable to presume others are where the same materials are associated without the coal. Mr. Lesley imagines that the Brandon deposit is in a hole, like that in Belymacadam, in Ireland. But if he will visit the former, he will find it no more and perhaps rather less in a hole than the other analogous deposits scattered for two hundred miles along the west base of the Green Mountain range. They generally occur in depressions in the limestone floor, or in sheltered valleys, and this is probably the reason why the drift agency did not sweep them away.

The heights of several of the Vermont deposits above the ocean attached to the preceding lists, excluding the Hartwellville locality as doubtful, show a difference of level of 735 feet—from 433 to 1168. We wish that similar facts had been ascertained in other parts of the United States. But taking these numbers as our guide, and supposing that the hematite and clay deposits could have been formed only at a certain depth in the ocean or estuary, would a vertical movement of the continent of 700 feet have been an impossibility during the pliocene tertiary period? If not, all these deposits, though superimposed upon rocks of different ages, might have been made during that period.

We see not then why we should give up the opinion that these deposits might have been of tertiary age. It is certain that they are not post-tertiary, we believe, and if we cannot conclude from such characters as we find them to possess, that they were arranged in their present form during the tertiary period, though disintegration and decomposition might have prepared the materials to be sorted, transported, and re-deposited by water much earlier,—then it seems to us that no deposit lying between drift and silurian or devonian rocks, where the intervening formations are wanting, can be pronounced tertiary, unless it contain fossils specifically like those of other tertiary strata. We are not prepared to take such ground. We have more confidence in geological principles.

We are not prepared to say that hematite beds, with clays and lignites, may not be found in the United States of an age older than the tertiary. But where we find by combining the facts from different localities, such strong proofs of identity and synchronism, as in the deposits stretching along the Appalachian chain, we cannot but regard them as of the same age till the contrary is proved. At any rate, if these strata are not tertiary, no such exist in Vermont. Brown coal is certainly dug out in Brandon, and it is interesting to see how well it drives the steam engine that pumps the water from the mine. We regret not being able to give a more satisfactory account of the fossil fruits. But having in vain brought them under the notice of some of the most eminent botanists in our country, and obtaining but little light, we can do little but give the brief description above, leaving the full development of the subject for those that come after us. The fossil botany of the newer rocks is now receiving more attention. But many years of study will be required to master it.

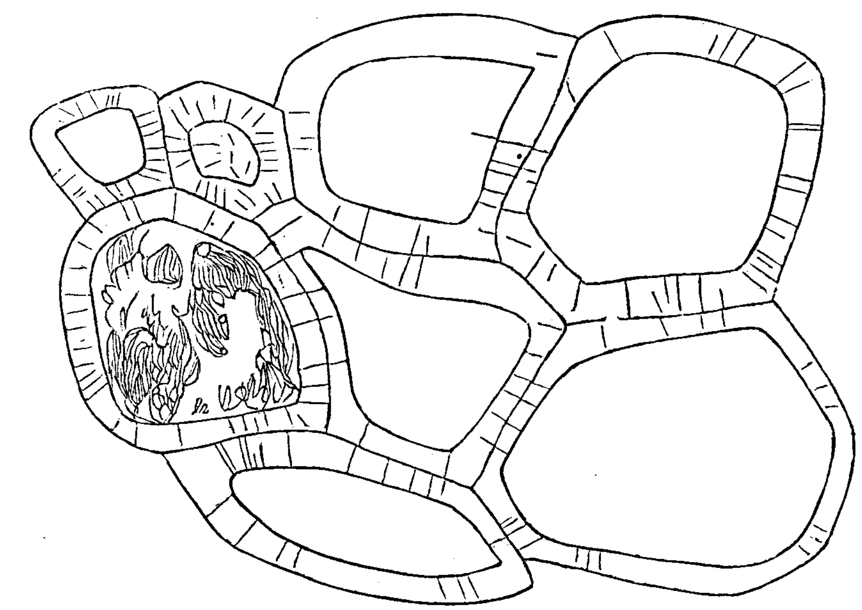
From one eminent microscopist, however, we did obtain some valuable facts relating to the lignite and fruits of the Brandon deposit. We sent specimens, seven years ago, to the late Prof. J. W. Bailey, of West Point, and received the following answer:

West Point, Dec. 10, 1852.

President Hitchcock:

Dear Sir,—The specimens of fossil woods and fruits from Vermont which you sent long ago, reached me safely, but I have been unable to attend to them until very lately. I have recently made sections of some of them for microscopic examination, but have obtained only negative results. The woods are *not coniferous*, and do not present characters by which I can distinguish them from many ductifferous woods. One of them is remarkable for a great number of large cells (for resin or oil) scattered in radiant plates among the "silver grain" or medullary rays. The small nut-like fruits, No. 13, have been studied by me most carefully, and at first were a complete puzzle, as the cross section showed nothing but "hard tissue" or "sclerogen" (Fig. 161, *bis*), without any distinct cavity for

Fig. 161. (*bis.*)



seeds, and yet its exterior markings (Fig. 162) and internal structure showed that it was probably composed of either three or six carpels, and if a capsule of course should contain seeds, or a place for them. By sacrificing the most perfect specimen I at last found the seeds, which appear to have been six in number, and arranged in a radiant manner around the axis, as indicated in the cross section (Fig. 163.) I succeeded in getting several seeds partly exposed, as in Figs. 164, 165 and 166. The testa alone of the seed is preserved and is

Fig. 162.

Fig. 163.

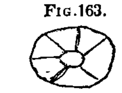


Fig. 164.

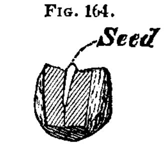


Fig. 165.

Fig. 166.

very brittle. I am not much versed in carpology, and therefore can aid you little in determining the family to which the fruit should be referred. It is certainly unlike any of our northern fruits, and I would suggest its comparison with some of the Sapotæ, among which occur hexamerous fruits, with the seeds united into a putamen. A putamen, or else an envelope, as in some of the palms, could alone furnish the "hard tissue" of which these fruits are almost entirely made up.

Of the other fruits I have as yet formed no opinion, nor obtained any results worth mentioning. If I should obtain any, I will let you know without delay.

With sincerest respect,

I remain yours very truly,

J. W. BAILEY.

One interesting conclusion is here hinted at by Prof. Bailey, viz., that these fruits, or rather the one he was describing, are not like any of our present northern fruits, but approximate to those of the torrid zone, such as the Sapotaceæ. This is just what we might expect from the principles of geology, if the deposit is as old as the tertiary. Yet how few can be made to realize that the Champlain valley once had a climate like that of the West Indies! that the western slope of the Green Mountains once formed the shore of a tropical ocean, or strait rather, and that along that shore grew tropical fruits, which were floated by rivers and currents into the region now called Brandon! Yet the conclusion forces itself upon the geologist; for even though he is unable to refer these fruits to existing families, he can see that they approximate to tropical rather than northern fruits. Almost all of them are mostly made up of the sclerogen or hard tissues found in one of them by Prof. Bailey, and are thus allied in this respect to the palm tribe, nearly all of which are inhabitants of the warmer regions of the globe.

Leo Lesquereux, of Columbus, Ohio, one of our most accomplished botanists, writes as follows concerning these fruits: "I am acquainted with the Brandon fruits from specimens (very few) presented to me, and especially from the excellent pages describing them in the 15th vol. of Silliman's Journal. Most of the fruits published, or rather figured there, can be referred to species of the upper tertiary. They agree especially with the flora of Oeningen, and I have no doubt that the Brandon lignites belong to the same epoch as the upper bed of the lignite of the tertiary. It is about what Prof. Hitchcock supposed in his paper. Nevertheless they cannot belong to the Pliocene. There is no living species among them."

CONCRETIONS.

Rounded masses of calcareous or silicious matter, or of hydrate of iron, occur in most of the rocks, and might as well be described in this place. They vary in size from those several feet in diameter, to those not larger than a millet seed, and have evidently been formed after the original production of the rock. The most perfect of these nodules are spherical; but they are often flattened, and made in fact to assume a vast variety of forms, some of them exceedingly singular. These bodies are called concretions, because they seem evidently to have been formed by the accumulation of matter around a center, by what is called molecular attraction. We have found three or four varieties of these bodies in Vermont deserving special attention, either from their nature or their forms.

In the granite of several localities we have spherical or spheroidal concretions, chiefly of black mica; the like of which we have seen nowhere else, nor any account of them.

We defer a description of these nodules to that part of our Report which treats of the unstratified rocks. So also we do of the nodular masses found in a few dikes of trap rocks. But there are two sorts of concretion in alluvial clay, whose description appropriately follows the more recent deposits.

There is a third substance that not unfrequently occurs in the form of small concretions in low grounds. It is an oxyd of manganese, called *Wad*. This is derived from the rocks by means of water, and deposited, like bog iron ore, in swamps. It occurs not unfrequently in the State.

I. CYLINDRICAL FERRUGINOUS CONCRETIONS.

These are the first variety which we shall notice. They occur generally in the upper part of the clay, where it begins to take sand into combination. They consist generally of small cylinders, which sometimes have a spheroidal head, larger than the stem. They are always peforated longitudinally, though the opening is often quite small. They stand perpendicularly in the deposit, and the cementing material appears to be iron. They are sometimes quite hard, but generally are easily broken. They have been regarded by some as fossils; but the more probable opinion is that they are concretions, formed around the roots of certain plants (e. g. species of Equisetum.) Prof. Adams deposited in the State Cabinet, which was burnt, nearly four hundred specimens from Colchester, and Appletree Bay in Burlington. But there is a duplicate set in the collection which he procured for himself, and presented to Amherst College. We have not deemed it important, however, to give sketches of any of these, since these would not cast any light upon their character or origin. We can only say that organic matter, such as the roots of plants, seems to exert an influence in some circumstances for the production of concretions.

II. CLAYSTONES.

These are the most abundant and remarkable of the concretions found in Vermont. Some very striking varieties occur there, which we have seen nowhere else. These bodies are generally known by the name of claystones. They occur in clay, and have the color of the clay in which they are found. They are in fact clay which is cemented by carbonate of lime. Sometimes they are complete spheres, which is in fact the normal shape of concretions, where the matter composing them is equally free to move in all directions and obeys the force of attraction at the center. But generally these conditions were wanting, and the claystones are flattened and made to assume almost every possible shape. A prevalent opinion is, that they have been worn into their present forms by water, because water washes them out of the clay banks where they were formed. But nothing is more absurd than to impute their shapes to the mechanical action of water. They are produced chemically, in clay made plastic by water, and probably holding in solution the carbonate of lime, by which they are cemented.

We present below several analyses of those bodies, made by Mr. Olmsted, the chemical assistant of Prof. Adams.

	Dummerston.	Addison.	Alburgh.	Pittsford.	Danby.	Shelburne.	Norwich.
Carbonate of Lime,	51.08	45.09	53.17	42.88	49.66	52.58	44.84
" of Magnesia,	5.40	17.34	2.48	3.76	1.59	5.31	3.26
Alumina,	28.40	21.13	20.95	19.10	12.60	7.30	8.50
Peroxyd of Iron,	8.12	1.73	6.76	8.81	8.68	3.02	5.32
Protoxyd of Manganese,	1.50	0.60	1.50	trace.	2.00	1.38	4.47
Silica,	8.08	16.18	12.40	25.99	16.18	28.70	29.08
Water,			3,48		9.32	1.71	4.53
	102.58	102.07	100.74	100.54	100.00	100.00	100,00

These concretions occur in Europe, and some years ago we analyzed a few from Sweden, with the following results:

	1st Specimen.	*2d Specimen.*
Carbonate of Lime, ...	60.33	61.26
Carbonate of Magnesia, ...	trace	1.40
Silica, Alumina, Iron, &c., . . .	35.20	32.20
Water, ...	2.67	3.44

These are certainly of essentially the same nature as the Vermont claystones, though containing more of carbonate of lime. Yet sometime ago "the Swedish scientific men believed them to be something of organic remains; some sort of mollusks, which were more or less wrapt in a mantle." They would abandon such an opinion were they to examine a collection of Vermont claystones.

Prof. Adams deposited nearly 900 specimens of these concretions in the State Cabinet, from the following towns: Sharon, Pittsford, Bethel, Charlotte, Montpelier, Brandon, Sudbury, Weybridge, Colchester, Mallet's Bay, Norwich, Orwell, Burlington (Appletree Bay), Ryegate, Shoreham (Larrabee's Point), Rutland, and Stowe. We have found several other localities noticed in the catalogue of rocks appended to our Report.

We have not found time to collect specimens anew, from the localities described by others; yet we have had access to the splendid collection presented by Prof. Adams to Amherst College, amounting to over 900 specimens, and from them have selected enough of the most peculiar forms to occupy Plates IX, X, & XI. Gladly would we give sketches of hundreds more, many of whose forms are very remarkable. But although the subject be a very curious one, we do not feel justified in giving more figures. The following are all which we present.

PLATE IX. Nos. 16 to 23 are spheres.

Nos. 1 to 15, and 24 to 29, are flattened spheres with rings or thick belts upon their margins.

No. 30 is flat but made up of numerous flattened rings firmly united.

Nos. 31, 34 and 35 are compounded with several smaller plates, upon a common plate.

No. 33 is a smooth plate with occasional nearly hemispheric bosses, which are usually hollow within, and the plate beneath is perforated. Probably the surface represented, is the under side. One of the bosses has a slit in it.

No. 36 is very thin, but shows numerous united flattened rings.

No. 37 looks like a dressed doll, or heathen image.

Nos. 38 to 44 are flat, with outer rings.

Nos. 45 and 46 are prolate spheroids.

Nos. 47, 51 and 52 are flat, showing two centers of attraction or formation, with a connecting strip.

Nos. 48, 49 and 50 are flat, with numerous belts, quite irregular.

No. 53 is a congeries of spheroids.

PLATE X. Nos. 1 and 2 are rounded, elongated, irregular masses. All the other numbers on this plate are examples of rings, either complete or interrupted. Some of them consist of several rings united, as if several cords or ropes of plastic matter were bound together. The largest of these rings is eleven inches in diameter, and this, like some of the others, is nearly a perfect sphere. They are, perhaps, the most remarkable of all the forms of claystones, and are found in Rutland.

PLATE XI. No. 1, flat and thin, with a single concentric belt on the margin.

No. 2 and 7 are flattened, but made up of several plates which look as if they had been formed by dropping successive portions of plastic matter upon the same spot.

In Nos. 3 and 4 the plastic matter seems to have mantled around the specimen in successive folds, the outer coats not always covering the inner ones throughout.

Nos. 5 and 8 are flat, with numerous small, often irregular plates, spread over the surface.

No. 6 shows two flattened circular plates with a connecting belt.

No. 9 consists of a thin plate of concretionary matter, covered over with numerous often compressed funnels, the narrow openings in which always passes through the plate. These curious forms will be more particularly described further on.

The sphere, which occurs in Sharon, Pittsford, Ryegate, &c., as already remarked, is the most perfect form of a concretion. But it is one of the rarest forms among the claystones, probably because it is unusual in such a deposit as clay, to have all the essential circumstances present for its production. It becomes an interesting question whether all the other forms can result from modifications of the sphere? The numerous forms which were described and figured in a report on the geology of Massachusetts, twenty years ago, we then thought might be derived from the spherical, by supposing obstructions to the concreting force, in various directions. Thus, suppose a nucleus or attracting center (it may be a fish, a shell, a pebble or grain of sand) to be established,—and the clay permeated by water, to be perfectly uniform throughout,—a sphere would result. But if the particles move more freely on two opposite sides, than on the others, a prolate spheroid would result. Or if less freely on these sides than the others, an oblate spheroid would be formed. If the particles move freely only in the direction of the lamination, a circular plate would result. Some such are more than five inches across, and not more than a quarter of an inch thick. Sometimes they are annular; that is, are made up of two, three or more, connected flattened rings, of slightly unequal thickness; as at the Norwich locality. This is difficult to explain. Nearly as difficult is the further fact, that a part of one or more of the outer rings is sometimes wanting,—so much of it, in some cases, that only a single ear or handle remains, and sometimes a part of the ring is removed on opposite sides.

Such flattened plates, made up of successive rings, have been called *annulated*. Sometimes such plates, not annulated, are drawn to an edge on their circumference, and are then called *lenticular*, as they really are; but by what modification of the formative force, we cannot say.

Again, it is easy to conceive how the process that forms the prolate spheroid might be continued till a cylinder was pruduced, longer or shorter, according to circumstances. Such cylindrical forms are not unfrequent: sometimes 6 or 8 inches long and half an inch wide. We have seen a few two and a half feet long and an inch wide, in the banks of Connecticut River, in Massachusetts, though a good deal flattened.

These six predominant forms may all be naturally derived from the sphere, and by combining them, we have thought hitherto that the immense number of complicated forms, which we had met, might have been produced. But in Vermont, at least two new forms occur, which we can by no ingenuity derive from the sphere or any of its modifications.

The first form is the *Ring*, of which we give several sketches of specimens from Rutland, where they are of extraordinary perfection and size, as seen on Plate X. The layer, as already stated, is eleven inches in diameter, and the ring is nearly circular in every part, except in two places, where it looks as if it had been welded together. The thickness of the ring is one inch. In Fig. 6 the ring is smaller, but more perfect. It would seem as if two forces must have been here concerned; one directed towards the axis of the ring, and the other towards its center. What could have been the nature of the latter, we are unable to conjecture; and to point out their conjoint action, demands a chemistry and a transcendental mathematics beyond our knowledge. Yet when the true solution of this problem is found out, it will doubtless be plain and easy, like the most of nature's operations.

The second new form is the *funnel-shaped*, or as it is technically termed, the *infundibuliform*. A sheet of the calcareous matter composing claystones, not more than a quarter of an inch thick generally, and with numerous small perforations, is spread out sometimes, we are told, several feet or even yards square. Projecting from one side of this plate—probably the under side—are numerous little funnels, usually from half to three quarters of an inch in diameter, and about the same height, the outer sides of which are claystone materials, and the inner side more sandy, the sand being highly micaceous. The tube of the funnels terminates in the perforations in the plate. Where the funnels are so numerous as to crowd one another, their broad extremities become polygonal—five, six, and seven-sided, at least. Attached to the sides at the angles, we see frequently spheroidal masses, rarely larger than a pea, of claystone matter, looking as if there was an excess of the material, which dripped down stalactite fashion.

These facts lead to the presumption that the funnels are on the under side of the plate, and were formed by the passage of the cementing material through the perforations, which formed successive increments by the same influences as those which formed the rings above described. The excess of matter dripped from the angles and formed spheroidal drops. The specimens in the Amherst cabinet were from Sharon, and were brought to light by railroad excavations. Mr. Hager has visited the locality, and thinks the funnels are on the under side.

PROF. ADAMS' VIEWS OF CONCRETIONS.

In his second Report, Prof. Adams gave an able view of the subject of Concretions, and proposed a classification which may be more acceptable than that we have indicated above. We quote two pages from his Report:

COMPARISON OF THE POWER OF CONCRETION WITH THAT OF CRYSTALLIZATION.

"The analogies between this power and that of chemical affinity are remote and but of little interest. President Hitchcock has remarked on some of its analogies with crystallization. It is remarkable that they are so many and striking, while the powers themselves are so unlike. Concretions are analogous to crystals in having a normal or primary form, although but one form probably exists in all concretions. In the concentric structure, they have a cleavage, which, like that of crystals, is parallel to the surface, of the normal form. They are like crystals in having numerous secondary forms, although these are not probably the result of inherent laws, but of external circumstances. They also, by coalescence, give rise to twin and multiple forms, as do crystals, and many of them in consequence of an indefinite number of approximate centers of attraction result in amorphous masses. More frequently than crystals, they include foreign substances, which probably modify the form. As the crystals of given localities often have some peculiarity in a predominant form, the same is true, as was first observed by President Hitchcock, of clay stones, both of the simple and of the multiple forms. As attachment to a support prevents the completion of a perfect crystal in that direction, so we have seen a similar effect to result from the attachment of the nucleus to a concretion.

"The relations of the power of concretion to that of ordinary cohesion, are more intimate than to that of crystallization; it is rather a case of resemblance than of analogy, and perhaps they are only modifications of each other. The tendency of ordinary cohesion, as is well known, is to form spherical bodies, when as in drops of water over a dusty floor, or in globules of mercury, the cohesion between particles of a given body is not interfered with by their cohesion with a foreign substance. May not the ordinary effects of cohesion be the results of concretion with an indefinite number of centers, so that distinct concretions sustain the same relation to the common amorphous bodies which distinct crystals do to bodies composed of crystalline grains? But we have introduced this subject rather to elicit, than to offer suggestions. It is obvious that the description and theory of concretions constitute a subject, which, although perhaps less extensive than that of crystalology, is as properly entitled to rank as a distinct science.

CLASSIFICATION OF FORMS.

"The classification of the forms of concretions, is not impracticable. The most important distinction is that of simple and of complex forms. The examination and classification of the former division, as we have seen, conduct us to some of the fundamental principles of the subject. The classification of the complex forms is not susceptible of precision, but as in the case of the analogous aggregations of imperfect crystals, it is serviceable for purposes of description. Their most striking characters appear in the number and the mode of grouping of their constituents. Different modes of classification may be required for the different classes of concretions — those which arise from igneous fusion — those which constitute or exist in limestone strata — the claystones — and perhaps the ferruginous cylinders of clay, and other less numerous and miscellaneous examples.

"The greatest variety of forms exists among claystones, and we have found the following arrangement convenient, although groups cannot be established, which shall not gradually merge into each other. This classification obviously is of little importance as exhibiting any principles, and may be compared to the classification of imperfect aggregate crystals into columnar, granular, &c. with their subdivisions. It is not even desirable to mingle specimens from different localities, since, as before remarked, the peculiarities are a matter of much interest. But the various forms from a given locality may be conveniently arranged by this system, with modifications in some cases.

The term nuclear we have introduced to designate a mode of formation, in which a concretion, probably after an interval in the process, becomes the nucleus of an external concretion, which is separated by a depression from the nucleus.

The concentric structure differs in not having a depression between the parts, which appear to have resulted from slight and regular intervals in the process.

A. Simple forms.
  1. Without apparent concentric arrangement.
  2. *Encyclica.*
    a. with concentric structure.
    b. *Nuclear.*

B. Primary compounds; simple or encyclic forms, united in the direction of the horizontal axis, that is, edgewise.
  3. *Dimera*, composed of two simple or encyclic forms.
    a. with concentric structure.
    b. *Nuclear.*
  4. *Decamera*, with four to ten parts.
    a. Elongated, parts less confluent.
    b. " " quite "
    c. not " " less "
    d. " " " quite "
  5. *Polymera*, with more than ten parts.
    " subdivided like the decamerous concretions.

C. Binary compounds, united in the direction of the shorter axis, face to face, in two layers.
  This and the following may be subdivided as their parts are dimerous, trimerous, &c.

D. *Ternary*, united in three layers.

E. The less common examples of four or more layers may constitute the last division.

The amorphous bodies resulting from confused concretion, with an indefinite number of centers, must be rejected from such an arrangement."

Concretions are the crystals of geology; that is, they sustain the same relations to the rocks, as crystals do to the simple minerals. But they seem to us not to have received the attention from geologists which they deserve. No Abbe Hauy has yet appeared to develop the fundamental principle of their formation. Few geological cabinets indeed, contain any large collections of them. The 2,000 specimens in the Amherst Cabinets, chiefly of claystones and ferruginous concretions, are much the largest number we have seen in any museum, and we trust they will furnish some future investigator of this subject with the means of developing the laws which have controlled the formation of concretions. They are mainly from Vermont and Massachusetts, and present an extraordinary variety of forms.

Why standard works in English contain so little upon concretions, save those of the oolite and magnesian limestone, we know not. Naumann, in his German *Geognosic*, gives the best summary description of them which we have seen; yet he says but little about their mode of formation, and does not even mention the claystones. If they were as remarkable on the continent of Europe as in this country, he would not have omitted them. Thirty years ago, however, Prof. Alexander Brongniart gave an able essay *Sur les Orbicules siliceux, or silicious concretions*, such as agates, in *Tome vingt-troisieme of the Annales des Sciences Naturelles.* He endeavored to show under what circumstances silex would assume a spherical or concretionary form, and when it would crystallize in an angular form; and he arrived at the following conclusions:

"When silex has been completely dissolved, and by consequence is in a perfectly liquid

condition, it has crystallized and produced hyaline quartz. But when it was in a gelatinous condition, it has produced such silex as occurs in agates and chalcedony.

"This theory of the formation of silicious concretions, may be reduced to the three following points:

"1. The silex that forms agates and chalcedony was not in a liquid or aqueous solution, but gelatinized.

"2. In becoming solid it did not crystallize, as that which separated itself from aqueous solution, and which produced hyaline quartz; but it took circular and spherical forms according to the position which it occupied.

"3. Organic matters appear to have had an influence on this secretion and this agglomeration of the silex."

This hypothesis appears to us extremely probable, and we think it may be extended further, so as to include a plastic as well as a gelatinous condition, and to embrace other substances besides silex. This substance is, in fact, the only one that concretes, which exists in a gelatinous condition sometimes. But silicates, carbonate of lime, hydrate of iron, &c., are frequently in a plastic state, as well as in a state of solution. Our suggestion is, that when in the former state, the regular bodies formed from it by molecular attraction, will have rounded forms, but angular forms when in a state of solution. The tendency of gelatinous silex is to the spherical form, as Brongniart has shown; probably it is the same with bodies in a plastic state, which is akin to the gelatinous. The reason of this tendency has not been discovered. But if proved as a fact, it will account for concretion. And we doubt not that taking this as a starting point, fixed laws may yet be discovered, by which the almost endless forms of claystones were produced. Different degrees of spissitude may have had something to do with the elimination of various forms. Common clay could not have had a temperature much above that of the atmosphere. But in the case of the nodules in granite, of concentric coats of mica and quartz, the heat must have been quite high, and we doubt not that these concretions have passed through a change of mineral constitution, analogous to the conversion of shale or sandstone into mica schist. What the nodules were before the metamorphosis, we cannot conjecture.

About twenty years ago the eminent microscopist, Prof. Ehrenberg, published the results of his examination of concretions with the microscope. The title of his essay was, *On the Forms assumed by uncrystallized mineral substances, called Kidneys, Imatru Stones, Claystones, &c.* Some of these, the *Imatru Stones*, had been described by Prof. Parrot as an extinct family of mollusks called *Imatru.* The Swedish claystones already referred to, are known in Sweden by the name of *Malrekor* or *Nockbroed*, and were called by Linnæus, *Tophus ludus* and *Merga porosa.*

These bodies, according to Ehrenberg, present no crystalline development, nor radiation, nor organic arrangement in their structure. They show "a solid circle which is several times repeated—an evidently active development in their formation, and founded on uniform laws, and frequently, perhaps always, parting from many axes of formation."—"Generally we perceive two directions of development in the laws of their structure; one concentric and sometimes horizontal, and in one direction (sense) only, which constitutes rays and discs, sometimes radiating on all sides, which produces spheres; the other is linear, and emanates from the center. For the most part these two axes exert a nearly equal power, or else one of them is superior to the other. It thence follows that the greater number of these *morpholites*, in consequence of the predominating influence of the linear direction of development, appear egg-shaped, or pisiform, or owing to the concentric direction prevailing, or the two forces being equal, assume the shape of discs or spheres, or are in an intermediate condition." Ehrenberg calls these bodies *Crystalloids*, or *Morpholites*. In Scotland they are called *Fairy Stones*.

ORIGIN OF QUARTZ FRAGMENTS IN THE COAL.

One fact, briefly alluded to in the preceding account of the Brandon Brown Coal, deserves further elucidation. This coal is in general remarkably free from the admixture of foreign substances, except that small grains of pure hyaline quartz are disseminated through almost the whole of it. They vary in size from bits a quarter or even a half of an inch across, to those so small that a microscope is needed to see them. They are not rounded like grains of sand, but look like crystallized quartz that has been crushed into fragments, though in a few cases they have the appearance of having been subject to some attrition. They are more abundant in some places than in others, but never lie crowded together like a mass of sand or gravel.

We are exceedingly puzzled to give any satisfactory explanation of these facts. We suggest three hypotheses, but neither of them satisfies us.

1. We may suppose that the currents of water that accumulated the vegetable matter, brought along also the fragments of quartz and diffused them through the peat. But why are not fragments of other rocks mixed with the quartz? I have in one instance seen a minute fragment of talcoid slate, but this was all among the thousands of angular bits of semi-transparent quartz. It is incredible that currents of water should have made such a selection, running as it did over rocks of various kinds. The quartz corresponds essentially to those white tubercular masses met with occasionally in the most thoroughly metamorphosed schists of the State. But how these could have been crushed into such small fragments, and selected from all other sorts of rocks and minerals, seems quite inexplicable.

2. We might suppose that the water which penetrated the deposit when in a course of formation contained, as the water of clayey deposits often does, a quantity of alkaline silicates, which, by the help of the organic matters, were decomposed and left the silica in the form of these fragments. The great objection to this hypothesis is, that quartz thus originating would not be left in the form of angular fragments, having the appearance of fracture, though the smallest particles might have been thus produced.

3. We might suppose that the fragments were originally of various kinds, but the alkaline water, with which the mass was permeated, aided by the reactions of the organic matters, dissolved and abstracted all the minerals except quartz. And it must be confessed that the grains of quartz often have the aspect of a ruin, or as if something had been abstracted from them, and these were left as an insoluble residuum. Their predominant angularity is the chief objection to the hypothesis; but upon the whole we look upon it as the most plausible of the three. If we had had access to the deposit, since our thoughts have been specially turned to the subject, something more satisfactory might perhaps have been suggested.

SIMPLE MINERALS.

BY E. HITCHCOCK, JR.

In the description of the minerals of Vermont, the principal authorities used will be Dana's System of Mineralogy, and Shepard's Treatise on Mineralogy, which are the most complete works on American Minerals in this country extant.

As these authors differ somewhat in their systems of classification, it may be well here, for the convenience of those wishing to study the minerals of Vermont, to have both systems briefly explained before attempting specific descriptions.

Prof. Dana considers all crystals as capable of being derived from thirteen shapes, called primary forms. These are the cube, regular octahedron, rhombic dodecahedron, right square prism, square octahedron, right rectangular prism, right rhombic prism, rhombic octahedron, right rhomboidal prism, oblique rhombic prism, oblique rhomboidal prism, the hexagonal prism, and the rhombohedron. These are grouped together under six systems:

1. *Monometric*, including the cube, regular octahedron, and rhombic dodecahedron.
2. *Dimetric*, the right square prism, and the square octahedron.
3. *Trimetric*, right rectangular prism, right rhombic prism, and rhombic octahedron.
4. *Monoclinic*, right rhomboidal prism, and the oblique rhombic prism.
5. *Triclinic*, the oblique rhomboidal prism.
6. *Hexagonal*, including the hexagonal prism, and the rhombohedron.

Prof. Shepard regards the primary forms of crystals as only eight in number. These are,—1. The cube; 2. The right square prism; 3. The right rectangular prism; 4. The right rhombic prism; 5. The right oblique angled prism; 6. The oblique rhombic prism; 7. The doubly oblique prism; and 8. The rhomboid.

In describing the minerals of Vermont, the plan adopted will be to give the primary form so far as it is known, and other physical characteristics. In addition to this will be given the chemical characters of the species, and a complete analysis of all Vermont minerals so far as they have been made. The practical uses of each species, too, will be added, so far as it is not the same as that mentioned under the head of Economic Geology, in this Report. A catalogue of all the Vermont localities will also be added to this part of the Report. The minerals will be grouped together under the rocks in which they occur. (D.) refers to Prof. Dana as authority, and (S.) refers to Prof. Shepard as authority.

MINERALS IN THE TERTIARY SERIES.

The minerals found in the Tertiary of Vermont are Pyrolusite, Psilomelane, Braunite, Brown Iron Ore, Yellow Ochre, Mountain Leather, Calcite, Kaolin and Lignite.

Pyrolusite. This is an important ore of manganese, known as the Anhydrous Binoxyd. Some varieties of it contain a trace of Silica and Baryta. This primary form is a right rhombic prism, and is often found columnar and granular. In color it is bluish-black, though often, as at Chittenden, it occurs in small brilliant, steel-gray crystals. This is often found in connection with other ores of manganese.

It is found in Vermont at Chittenden, Bennington, Brandon, Irasburgh and Monkton.

In the State Cabinet it may be seen under the Nos. 79 to 90 inclusive.

Psilomelane. This is another common ore of manganese, a hydrated oxyd, which occurs not in crystals, but in mammillary masses, of an iron-black color, passing into steel-gray, with submetallic luster.

This at Bennington, Chittenden, and Brandon is found in connection with Pyrolusite.

It is found in Vermont at Chittenden, Bennington, Plymouth, Brandon, Irasburgh and Bristol.

It may be seen in the Cabinet in connection with nearly all the other specimens of manganese.

Braunite. This is another of the oxyds of manganese, though not of so frequent occurrence as the two last described. It belongs, in crystalline form, to the Dimetric system of Dana. It is brittle, with a submetallic luster, and of a dark brownish black color.

It is found in Vermont at Brandon, Chittenden, and Pittsford ? Wallingford? Bristol?

Brown Iron Ore, or Limonite of Dana. This is the hydrous Peroxyd of Iron, and occurs usually in reniform, stalactitic, or botryoidal masses, with a fibrous structure. Sometimes it is massive, and sometimes earthy, but is never crystallized. In color it is brown with its various shades; sometimes nearly black Brown iron ore is one of the most important ores of iron, making that metal which is readily convertible into steel, especially if the ore is reduced by charcoal.

It is found in Vermont at Bennington, Monkton, Pittsford, Putney, Ripton, Sherburne, Chittenden Dorset, Manchester, Stamford, Swanton, Bristol, Huntington, Starksboro, Highgate, Warren, Colchester, Milton, St. George, Brandon, E. Bennington, E. Shaftsbury, S. Wallingford, Plymouth.

Specimens of brown iron ore may be seen in the Cabinet from Nos. 102 to 112 inclusive.

Yellow Ochre. This is an earthy ore of iron probably of the same composition as limonite and hematite. It is of a yellow color and often of a consistency of chalk. It is obtained abundantly at all the localities where limonite is found in Vermont, and is easily obtained by washing and subsequent deposit. At Brandon and Bennington it is procured in immense quantities.

Specimens of yellow ochre are to be seen in the Cabinet under Nos. 124 and 125.

Red ochre is not found in nature, but is simply the yellow treated to heat. In this case the iron is carried to another stage of oxydation.

Mountain Leather. This is a fanciful name given to one of the kinds of asbestos, which is itself a variety of hornblende. It occurs in thin paper-like masses, lying between different portions of a rock, and the fibers are so small and closely interlaced that the whole has an appearance more like leather than like an interlacement of fibers. Another name given to essentially the same thing is mountain or rock cork, since masses of it are of so slight a specific gravity that they will float on the water.

This mineral has been found in Swanton, and is No. 220 in the State Collection of Minerals.

Kaolin or Porcelain Clay. This should hardly be regarded as a simple mineral, since it exists in consequence of the decomposition of simple minerals — the feldspars. Prof. Dana says : "When the infiltrating waters contain traces of carbonic acid, the feldspar acted on first looses its lime, if a lime feldspar, by a combination of the lime with this acid ; next its alkalies are carried off as carbonates, if the supply of carbonic acid continues, or otherwise as silicates in solution. The change thus going on ends in forming kaolin or some other hydrous silicate. The carbonate of soda or potash or the silicates of these bases, set free, may go to the formation of other minerals — the production of pseudomorphic or metamorphic changes and the supplying fresh and marine waters with their saline ingredients." It is not easy always to distinguish this from the following variety.

Pipe Clay is found in several places in Vermont, among which may be mentioned Plymouth, Bennington, Pownal, Brandon and Monkton. It is found of different qualities and colors, as will be described under Economic Geology.

Closely in connection with the kaolin of the tertiary series, should be mentioned the *lignite* or *brown coal.* It occurs abundantly at Brandon where it was used as fuel for the steam engine at the shaft. With it are also found fruits, evidently belonging to the wood now converted into lignite. No similar fruits have as yet been discovered on this continent elsewhere than at Brandon, though they occur in the Isle of Sheppey, England, and in the brown coal of Germany. These, however, have been already described.

No 10 in the cabinet is a specimen of lignite from Brandon.

PART II.

HYPOZOIC AND PALÆOZOIC ROCKS.

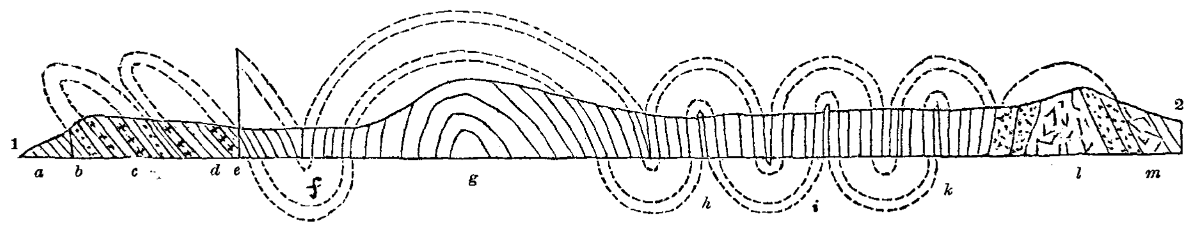
BY E. HITCHCOCK, SENIOR.

These rocks, with one or two unimportant exceptions, occur only in that part of the State west of the Green Mountains, so far as has yet been ascertained. We find there a succession of formations, whose order of superposition is settled in other parts of the country, and in some cases in Vermont ; but often in consequence of inversion, faults and metamorphism, it is obscure and undetermined. These rocks are the oldest of the stratified class on the globe. Of the hypozoic series, Vermont contains, so far as we yet know positively, only a small belt, which is, however, the eastern edge of an immense development of the same in New York. The oldest of the palæzoic series lies directly upon the hypozoic, at least in one point ; and from thence, as we proceed towards the Green Mountains, we can trace the usual order ; not, however, in many cases without supposing that the strata have not only been folded together by some lateral force, but actually thrown over, so as to produce inverted dips; and not only so, but that there have been extensive risings and sinkings of strata along extended cracks or faults. Still, so long as the fossils are not obliterated, the order of superposition can be traced out. But as we approach the Green Mountains, metamorphism has so nearly destroyed the fossils, that the identification of the strata becomes extremely problematical, until at length we lose the clue entirely, and can only conjecture the age of the formations. Could we keep hold of it, Part II. would probably embrace all the rocks of the State ; but since those in and east of the Green Mountains must be distinguished mainly by their lithological characters, we group them into a third class, and offer only conjectures as to their age.

Before entering upon a detailed description of either of these classes, a few preliminary remarks seem desirable, especially for such as may not be familiar with the phenomena of plication, inverted dips and faults.

The prevailing dip of the rocks of Vermont is easterly, or rather somewhat southeasterly. This is particularly the case with the fossiliferous rocks. But an inspection of our sections will show that the exceptions are very numerous in the other parts of the State. A large number of anticlinals and synclinals exist, and of course frequent westerly dips. The whole is reasonably explained by supposing the strata to have been crumpled up by a force coming from the southeast; the effects modified, perhaps, in some cases by protrusions of granite ; and since the time of disturbance and plication, the tops of the folds have been worn away, so as to leave only the outcropping edges of the strata in sight.— The various sections we shall give, afford illustrations of all these phenomena. But we bring them together in the following sketch, which was not taken from nature ; yet there is a general correspondence between this section and those we have given crossing the State, say the one from Guildhall to Sister's Island, No. XI.

Beginning at the left hand or west end of the sketch below, we have represented, at *a*, a few fossiliferous strata, lying upon hypozoic rocks, with a moderate easterly dip, having



experienced no other disturbance than an elevation of their western side. Proceeding easterly, we come to a fault, *b*, along which the rocks lying east have been raised, so as to bring those older than *a* into view; yet as they have about the same easterly dip, and the fault is hidden by detritus, the fossils alone inform us that they are older. We suppose, too, that they may have an inverted dip; that is, have been thrown over, so as to bring the newer strata at the bottom. We have represented two folds, *c* and *d*, of these rocks, and then a second fault, *e*, succeeded by a synclinal fold, *f*, followed by rocks, it may be older, it may be newer, but essentially conformable to those between the faults. The line, 1, 2, represents the present surface, and the dotted curves above this line show the surface as it was after the original plication, before erosion had taken place. These curves are represented as extending below the bottom of the section, to show into what position the plication of strata would bring them could we get at them deep in the earth. Beyond *f*, we have shown a broad anticlinal, *g*, which may or may not be inverted, though in the synclinal, *f*, inversion is manifest. Beyond *g*, we have drawn three folds, *h*, *i*, *k*, exactly alike, supposed to have occurred in the same homogeneous rock, so that when erosion has swept off the curves down to the line, 1, 2, the rocks would show merely a succession of perpendicular strata, exactly alike, and we could not tell how many folds were present. Beyond *k*, we have shown a mass of unstratified rock, *l*, lying beneath the stratified; the latter resting upon the former with outward dips, as if the unstratified mass had been protruded from beneath. More commonly however, in Vermont, and indeed through the whole country, the unstratified rocks occur in thick beds in the stratified, with the same dip, as shown at *m*.

Now this section gives a general idea of the leading facts which geologists suppose may be seen in crossing the northern part of Vermont, from Lake Champlain to Connecticut River. From *a* to *b*, for instance, we have some of the oldest fossiliferous rocks (Potsdam sandstone, calciferous sandstone, &c.) lying upon hypozoic gneiss. Then comes an uplift along the fault, *b*, which brings up perhaps the primordial zone of Canada, which embraces rocks at least as old as the Potsdam sandstone, and as Professor Emmons thinks, those still older, especially on the second fold, *d;* for both folds may have inverted dips. The synclinal fold, *f*, may represent the talcose schists west of the Green Mountains, whose age, as they have no fossils, is only conjectural. The broad anticlinal fold, *g*, resembles that of the Green Mountain range in some places, where we find several varieties of rock folded together, generally with inverted dips. The succession of folds, *h*, *i*, *k*, may represent the wide belt of talcose schist generally found along the eastern side of the Green

Mountains, whose great thickness—sometimes as much as ten miles—forbids the supposition that it could be only a single fold, and compels us to believe that the same strata must have been doubled several times, and so brought into apposition, with a nearly perpendicular dip, that we cannot distinguish one fold from another. We know of no other way to explain the enormous thickness of these strata, unless it be to suppose what seem to be strata to be in fact only foliation or cleavage, which have been superinduced, and do not correspond to original stratification. We doubt not that these structures are superinduced and do sometimes intersect the planes of stratification and lamination. But the not unusual occurrence of beds of quartz, and sometimes feldspathic compounds, whose bounding planes are parallel to those of the schist, shows that the foliation and cleavage do generally correspond to the stratification. Hence where we find enormous thicknesses of homogeneous schists, whether with inverted or normal dips, the most simple explanation is, that they consist of a succession of folds so closely appressed that we cannot tell where one ends and another begins.

To the right of the folds, *h*, *i*, *k*, on the preceding diagram, we have represented stratified masses mantling over an unstratified mass, though the upper part of the fold has been denuded. Such cases may be found occasionally in the eastern part of Vermont, as our general sections will show, say Sections III, IX, X and XII. Still more to the right we give a mass of unstratified rock, *m*, lying as a bed between the strata; which, as already stated, is the most usual mode in which such rocks occur in Vermont; as for instance at Ascutney and Greensboro, and on several of the more northern sections.

Where several rocks are interstratified, it is frequently not difficult to determine the limits of a fold, even though we have only parallel strata with the same dip, and that an inverted one, as at *c*, on our section. For we find a similar succession of rocks in passing each way from the axis of the fold. Several are represented on *c*, with an inverted dip, and the same number on *g*, with a dip partially inverted.

It is often a very difficult matter to ascertain whether a rock is inverted or in a normal position. If the former, we shall find ripple marks, tracks, rain drops, and fossils, bottom upwards. Yet it is not easy always to settle this point; and many rocks have no such appearances from which to judge.

If strata have been thrown over so as to form an inverted axis, the natural inference is, that the newest formations will be found at the bottom, and the oldest at the top. But this is true of only one side of a fold. Thus in the fold, *c*, it is only the rocks on the left hand side of the axis that present an inverted order; those on the right hand side are in their normal position. In the synclinal fold, *f*, the left hand branch of the fold is in a normal position, the right hand slightly inverted; but as there is only one sort of rock, we cannot point out the part that is inverted. In the fold, *g*, the strata on both sides of the axis are in a normal position; so in the folds, *h*, *i*, *k*, the strata being perpendicular, we cannot say that some layers are above or beneath the others. As a matter of fact, however, in Vermont the talcose schist which these folds loosely represent, generally has a high southeasterly dip, which according to the reasoning above, will make the left hand side of the folds in an abnormal position, and the right hand side normal.

If these illustrations be admitted as giving an approximate idea of the position of the rocks in Vermont, and of the manner in which they have been plicated and overturned, some conclusions of importance follow. And first, if the strata have been folded by a force from the southeast, crowding them northwesterly, or rather almost westerly, we should expect, notwithstanding powerful denudation, to find evidence of the plicating force in the form of anticlinals and synclinals, running nearly lengthwise of the State. Let us see whether such exist.

We begin with the section (Plate XV), crossing the north part of Massachusetts, a little south of Vermont. Towards its east end we find a distinct anticlinal at Shelburne Falls, whose lowest part is gneiss, overlaid by hornblende and mica schists. Looking at the first section, we see in Guilford a continuation of the same anticlinal, though smaller perhaps because less denuded. So on Section II, in Brattleboro; on Section III, in Newfane; on Section IV, in Grafton; on Section V, in Windsor (thus far the axis is in gneiss); on Section VI, in Hartford, in calciferous mica schist; on Section VII, in Sharon, in mica and hornblende schists; on Section VIII, between Corinth and Washington, in mica schist; on Section IX, in Orange, in mica schist, with a granitic axis; on Section X, in Peacham and Marshfield, with a broad granitic axis; on Section X *a*, in Danville, in mica schist; on section XI, in Sheffield, in mica schist, with a granitic axis. In the two northern sections the great development of granite may have destroyed this anticlinal; but it seems manifest on all the others though somewhat tortuous in its course.

We think another important anticlinal occupies the crest of the Green Mountains, mostly in gneiss. On the Massachusetts section in Florida, and Section I, in Readsboro; Section III, in Stratton; Section VI, in Sherburne; Section VII, in Goshen, and Rochester; and Section VIII, in Granville, the strata all dip to the east; but as this is probably an inverted dip, the whole may be an inverted anticlinal. But the occurrence of opposite dips in Searsburg; on Section II, in Peru; on Section IV, in Mt. Holly; on Section V, in Bolton; on Section IX, in Duxbury; on Section X, in Underhill and Stowe; on Section X *a*, and in Johnson on Section XI, all of which are along the crest of the mountain, makes it almost certain that an anticlinal exists there, and that the inverted dips on the other sections may be folded anticlinals. The same is probably true of Section XII, between Lowell and Montgomery, although the strata lean slightly towards the east, and therefore the anticlinal is not inverted; but it may be closely folded. Still more obviously is there an anticlinal on Section XIII, in Jay, where the rock is talcose schist; but it is doubtless a continuation of the Green Mountain chain.

Synclinals parallel to the above anticlinals can be traced on the sections. Most of them are remarkably sharp, bringing the strata into an almost perpendicular position. One may be seen along the junction of the calciferous mica and talcose schists; as in Charlemont, on the Massachusetts section, in Halifax on Section I; between Brattleboro and Marlboro on Section II; in Wardsboro, in gneiss, on Section III; in Grafton, in gneiss, on Section IV; in gneiss and talcose schist on Section V, in Cavendish; in mica schist in Woodstock, on Section VI; in talcose shist on Section VII, between Bethel and Rochester; in Roxbury between talcose schist and clay slate, on section VIII; in talcose schist in Middlesex, on Section IX and X; between talcose and mica schist in Hardwick, and a second in Morristown, on Section X *a*; in talcose schist in Hydepark, on Section XI; between talcose schist and clay slate in Lowell and Irasburgh, probably on Section XII; and between the same belts of slate in talcose schist in Newport, on Section XIII.

The above synclinal seems, for the most part, to follow the somewhat crooked course of the talcose and associated schists, along the east side of the Green Mountains. Passing westerly across the principal crest of the mountain, we find in the same rocks a similar syniclinal, which follows the west base of the mountains, probably through the whole of New England. It seems as if the schists were not only crumpled together, but pressed down by the lateral thrust of the mountains towards the west. The synclinal is most distinct on the northern sections, as in Berkshire on Section XIII; in Montgomery on Section XII; in Cambridge on Section XI; in Jericho and Underhill on Section X *a*; in Huntington with inverted dips, on Section X; in Richmond on Section IX; in Ripton and Middlebury with inverted and irregular dip, on Section VIII; the same on Section VII, between Brandon and Goshen; and on Section VI, between Rutland and Mendon; between Tinmouth and Wallingford on Section V, it is more distinct; so also in East Dorset, on Section IV, and in Sunderland, on Section III. On the other two sections it is obscure, or rather it is with difficulty traced out on account of the great amount of detritus. But on the Massachusetts Section there seems to be a quite distinct synclinal on Saddle Mountain. We doubt, however, whether it belongs to the synclinal we have been tracing southerly. Still we believe in the continuance of this synclinal all along the west base of the Green Mountains, across Massachusetts. It has always seemed to us as if the rocks had been crowded harder against one another in the vicinity of Saddle Mountain than almost anywhere else; so that the synclinal we have described is crowded into very narrow limits between Saddle and Hoosac Mountains.

Saddle Mountain and its vicinity are a region of perhaps more difficulty to unravel than any other place west of the Green Mountains. We have been there often, and Prof. Emmons has lived there, and no doubt studied the position of the rocks with great care. Our Massachusetts Section conforms essentially to his views. This represents an enormous thickness of talcoid schists, forming a synclinal trough, above white crystalline limestone. If we go north as far as Bennington, we find a similar arrangement; that is, talcoid schist overlying Eolian limestone, with a westerly dip, on the east side of Mount Anthony, and a slightly eastern dip on the other side as shown on Section II. The same thing is seen in Arlington on Section III; though the limestone lies much lower, as we see in passing down the Battenkill through the Taconic range. Further north, in Manchester, Equinox Mountain presents the same phenomena, and here the limestone rises much higher. But the most complete development of the limestone occurs in Mt. Eolus, in Dorset, as seen on Section IV, where the cap of talcoid schist is comparatively thin; but it forms an open synclinal, as it does on Danby Mountain, a few miles north. On Section V, between Wallingford and Tinmouth, a synclinal is seen, but its exact character has not been traced out. In Rutland on Section VI, we have the same rocks, but the dips are all easterly, and the great body of talcoid schist lies beneath the limestone. May not this be an inverted anticlinal formed out of the synclinal? For if the sides of a synclinal be closely pressed together, so as to make the strata parallel, and then the whole be thrown over, and the curves all denuded, we could not easily distinguish a synclinal from an inverted anticlinal. We fancy that something of this sort may have thus changed the synclinal we have been describing, as we go north of Mt. Eolus,—so that on Section VI. in Rutland, on Section VII. in Sudbury, and Section IX. in Essex, we might describe these rocks as forming an inverted anticlinal; while in Middlebury they appear to be a true synclinal.

Several shorter anticlinals and synclinals can be traced upon our sections, but the preceding are all which we have been able to discover extending through a large part of the State. Our sections were all traced out in the field and protracted on paper without the slightest knowledge of their existence. So that although a re-examination of the sections may produce some modifications in the dips, we are confident that the great features will remain. Hence we may feel confident that the rocks of Vermont have been thrown into a succession of folds while in a semi-plastic condition by a force from the direction of the Atlantic, and that their crests have been subsequently denuded.

One important inference from these statements is that only a part of the strata as we cross the State can be regarded as lying in an inverted position. Certainly those with westerly dips forming the western side of anticlinals must occupy a normal position.— And so must the eastern side of those anticlinals that have been inverted. Hence, though we cross an uninterrupted succession of easterly dips in going eastward we cannot infer that we are constantly meeting with older and older rocks. It may be so for a time; but if there have been successive folds, one side of the folds may be in a normal position. If organic remains are wanting and we cannot discover other proofs of inversion, we shall be unable to say where the change takes place from a normal to an abnormal position, and the reverse. And this may be a chief reason for the discordant views that have been advanced by geologists, respecting the age and position of the Vermont rocks. In many cases the evidence necessary to settle these questions, may never have been or never can be discovered. Yet we feel confident that careful and prolonged researches will furnish data for the solution of some of them.

Another inference is, that mere superposition will not justify us in deciding upon the relative age of rocks. The questions we must previously settle are, whether the strata at the line of junction are in a normal or inverted position; or if inverted, which side of the anticlinal or synclinal is it, that we are examining? And if, as often happens, we cannot decide these questions, the main question as to relative age must be left undecided.

Unfortunately this reasoning applies to many of the questions, as to the relative age of the metamorphic schists of Vermont, whose details will be given under the different rocks. We are sorry to be obliged to confess that there is so much uncertainty upon this point. But it will at least justify our hesitancy and caution on this subject.

Another important conclusion from our discussion is, that if the rocks of Vermont have been thus folded up and deeply denuded subsequently, then it may be that some of the oldest of the rocks may be brought to light at the centers or axes of the folds. Take, for instance, the first anticlinal described above, extending from Shelburne Falls, in Massachusetts, nearly through the State of Vermont. At Shelburne some 10,000 feet of schist have been worn away, bringing gneiss to light at the bottom, and this rock is brought to light on the first five sections, north of which the mica schist is not denuded deep enough to expose the gneiss. Why may not this gneiss be hypozoic? Surely the strata above it that are denuded, are thick enough to embrace the silurian rocks, and there is no evidence of cambrian strata in Vermont east of the taconic schist. The same reasoning may apply to the gneiss of the anticlinal running along the crest of the Green Mountains. In some of its lowest places, as at Mount Holly, where at least 8,000 feet of strata have been denuded, it is possible that some of the oldest rocks may be here brought into view. Hence we think it a hasty conclusion to infer positively that none of the rocks in Vermont, and probably not in New England, are older than the silurian. It may be so, but it reremains to be proved. Long and patient research will be requisite to prove the true age of all our metamorphic foliated rocks.

In these preliminary remarks we have been obliged to presume upon some knowledge at least, of all the rocks yet to be described. For the relations of these rocks could not be well understood without these preliminary principles. Any one who chooses, after he has read the detailed description of the rocks, can revert to these principles, and he will understand them better. Having given this *exposé*, the Principal of the survey will now introduce the detailed descriptions, all of which in Part II. have been prepared by C. H. Hitchcock, because he has had an opportunity to study them in the field more thoroughly than it has been possible for the Principal to do.

The following is a list of the rocks occurring in Vermont, and embraced in Part II, reckoned in an ascending order; though in regard to the position of those above the Hudson River Group, we have little but conjecture to guide us:

LAURENTIAN OR HYPOZOIC GNEISS.	HUDSON RIVER GROUP.
POTSDAM SANDSTONE.	RED SANDSTONE SERIES.
CALCIFEROUS SANDROCK.	QUARTZ ROCK.
CHAZY LIMESTONE.	GEORGIA GROUP.
BIRDSEYE LIMESTONE.	TALCOSE CONGLOMERATE.
BLACK RIVER LIMESTONE.	EOLIAN LIMESTONE.
TRENTON LIMESTONE.	TALCOID SCHISTS.
UTICA SLATE.	UPPER HELDERBERG LIMESTONE.

These rocks embrace nearly all the fossils found in the State, excepting those of the tertiary and alluvial. The descriptions of the fossils have been taken from the highest palæontological authorities, especially from Prof. James Hall, of Albany. To him, as stated elsewhere, we have been indebted for giving names to the specimens and describing the few new species which we have found.

LAURENTIAN SYSTEM.

The oldest rocks upon the globe, or the *bottom rocks*, have been denominated by Sir W. E. Logan the *Laurentian System*, because they are well developed in the Laurentine Mountains in Canada. This is the best local name for rocks of this age that has ever been proposed in this country; and we therefore use it to distinguish a particular belt of rock in Vermont. This appellation distinguishes the ante-Cambrian crystalline rocks from the metamorphic strata occupying most of the area of Vermont, as well as of New England. It has been supposed by most geologists (and the view is still held by some), that all the azoic rocks of New England are of the same age with those in northern New York and Canada, i. e., hypozoic. But considerations will be presented in this Report to show that probably most of the azoic rocks of Vermont are more recent than the Laurentian; and that consequently the separation of the azoic rocks into the Laurentian system and those that lie upon it, as the schists and slates of Cambrian, silurian, and Devonian ages, is legitimately called for by the progress of knowledge.

The area occupied by Laurentian rocks in Vermont is so limited, that it would hardly be worthy of special notice, did it not form so convenient a starting point in the description of the geology of the State. We are enabled, with a brief introduction, to commence the description of the oldest rocks on the continent from which relics of animal and vegetable life have been exhumed. According to most geologists, we are ushered from a period of darkness and death to a time of light and life. Standing upon the Laurentian fragment, one can see only a waste barren region, destitute of animated existence, scarcely elevated above the shallow ocean, and yet warm from the influence of the primitive globe of molten fire. Ascending a step, and we rest upon a silurian foothold, and the earth appears rejoicing in the vigor of youth, commencing the oft repeated cycles of organic development, which find their perfection in the alluvial period.

All the Laurentian rocks in Vermont are upon a narrow spur projecting, like an arm, from the great nucleus of older rocks in northern New York. It enters the town of West Haven directly opposite the terminus of the railroad at the steamboat wharf in Whitehall, and extends three or four miles to the north. It is everywhere quite narrow. The only way of distinguishing the Laurentian character of the deposit is by the higher dip of its strata, upon which the Potsdam sandstone reposes unconformably. A section passing across the south end of West Haven, in Fig. 168, represents the unconformable relations of the Laurentian rocks and the Potsdam sandstone to each other. Were it not for this discordance in the stratification, we should regard the lower rock as silurian, because it does not differ lithologically from the sandstone above. But in following the strata northwardly, the quartz rock becomes more gneissoid. Some of the specimens in the Cabinet, Nos. $\frac{6}{134}$, $\frac{6}{135}$ and $\frac{6}{136}$, are very distinct gneiss, one of them with the Labradorite, the characteristic species of feldspar of the Laurentian series.

We have noticed the following strikes and dips of the strata :

Locality.	*Strike.*	*Dip.*	*Observer.*
Whitehall, N. Y.,	East of north,	30°–40° E.,	E. H.
West Haven, southwest corner,	East of north,	36° E.,	C. H. H. and E. H., jr.
West Haven, do.,	N. 10° E.,	35° E.,	C. H. H. and E. H., jr.
West Haven, on Lake Champlain,		17° N. E.,	C. H. H.
Garfield's Landing, N. Y.,	N. 45° E.,	25° S. W.,	C. H. H.
Split Rock, N. Y.,		34° E.,	Z. T.

Probably this range of gneiss has been elevated to its present position, while the calciferous sandrock and Potsdam sandstone upon the west side have not been disturbed, and are now at a lower level than the gneiss, in consequence. As the gneiss rose, the sandstone overlying it also rose, and now form the range of hills, of which Bald Mountain is the most conspicuous. Consequently we find two different bands of calciferous sandrock, the one east and the other west of the gneiss. The effect of the upheaval is not seen upon the line of the strike of the geniss, in the north part of West Haven, for the calciferous sandrock there entirely covers it, having never been separated into two parts by the elevating agency.

Should the discussion now commenced anew in the scientific world respecting the age of the Georgia Group and the Red Sandrock series, result in the establishment of their primordial character, the presumption will arise that the azoic rocks of New England are still older — perhaps even laurentian. Hence we await with much interest the development of opinion on these subjects.

LOWER SILURIAN ROCKS.

The geologists of New York have referred to the lower silurian period, several groups of rocks immediately overlying the azoic rocks in the northeastern part of their State. The same terrains are continued into Vermont; and we endeavored to trace them out, and have represented them upon our Geological Map. Local names were given to these groups, and they are the following, as developed in Vermont. We give them in the ascending order:

POTSDAM SANDSTONE.
CALCIFEROUS SANDROCK.
CHAZY LIMESTONE.
BIRDSEYE LIMESTONE.
BLACK RIVER LIMESTONE, OR ISLE LA MOTTE MARBLE.
TRENTON LIMESTONE.
UTICA SLATE.
HUDSON RIVER GROUP.

To these, in connection with the red sandrock series, which was supposed to overlie the Hudson River Group, the general name of *Champlain Group* has been applied, from their occurrence in the valley of Lake Champlain.

Lithologically these lower silurian rocks may form three divisons, viz: sandstone, beds of limestone and clay slates. But the more complex classification we have given, is necessary only on account of the distribution of organic remains through the series. Some authors have arranged these divisions into three general groups, which correspond essentially to the natural lithological arrangement. On this view the smaller divisions are called *Epochs*, and the larger divisions *Periods*. It regards the rocks historically, not merely lithologically and palæontologically. The following is the proposed system:

I. POTSDAM PERIOD.
1st Epoch, *Potsdam Sandstone.*
2d Epoch, *Calciferous Sandrock.*

II. TRENTON PERIOD.
1st Epoch, *Chazy Limestone.*
2d Epoch, *Birdseye Limestone.*
3d Epoch, *Black River Limestone.*
4th Epoch, *Trenton Limestone.*

III. HUDSON PERIOD.
1st Epoch, *Utica Slate.*
2d Epoch, *Hudson River Group.*

Our chief objection to this classification is the use of the term *epoch*. An epoch is the point of time when an event takes place, not the interval between two points of time, which is properly a period.

In speaking generally of these different formations, we may say that the Potsdam sandstone is a purely silicious sandstone; the calciferous sandrock is intermediate in character, as it is also in position, between purely silicious and purely calcareous beds; the chazy limestone, birdseye limestone, Black River limestone and the Trenton limestone are tolerably pure limestones; the Utica slate is a slaty limestone or calcareous slate, forming a transition between the limestones below, and clay slates above. The Hudson River group is chiefly clay slate, but includes also much calcareous slate and thick beds of limestone in its upper portion.

The Potsdam sandstone rests unconformably upon crystalline rocks invariably. In general the higher formations of the lower silurian series rest conformably upon the Potsdam sandstone, and upon one another. There are generally a few degrees of difference in the dip between the Hudson River group in Vermont and the overlying red sandrock.—Many geologists do not think this difference sufficiently great to be ranked as a constant unconformability.

SNAKE MOUNTAIN SECTION.

Upon none of the large sections appended to the Report is there a complete view of the lower silurian rocks. All of them, however, except the first five, embrace some of them. There is no place in Vermont where the whole may be found in direct succession. They are all exhibited, except the Potsdam sandstone, upon Snake Mountain in Addison. To illustrate this group of rocks we will give a detailed account of this section. For sections illustrating the position of the Potsdam sandstone we refer to figures under the description of that rock, which show its relations to the Laurentian gneiss below, and the calciferous sandrock above.

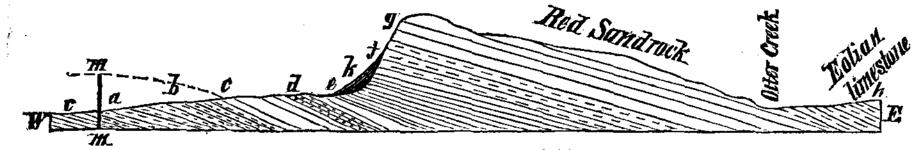
Snake Mountain is one of the most noted localities in Vermont, as respects Geology.—It was first described by Prof. Emmons in his Report upon the Geology of the Second District of New York, pages 279—282. This account is in accordance with our views.

Prof. Adams gave a section of the rocks of this mountain in his Second Annual Report upon the Geology of Vermont, pages 162, 163. We find little that is essential to add to his account, except to draw it out more fully.

Prof. Emmons having become convinced that there is a system of rocks containing fossils below the lower silurian (which he has given the name of *Taconic*), re-examined Snake Mountain subsequently to the publication of his Report, and came to the conclusion that in addition to the calciferous sandrock, chazy limestone and Trenton limestone, at the base of the mountain, the *black slate* of the Taconic System was present (what was before called Hudson River slates), underlying the calciferous sandrock; the rock which he had previously called the equivalent of the *gray sandstone*. These new views are brought out in the first volume of his work on North American Geology, Vol. I, Part II, pages 87, 88 and 89.

It will be seen from this section that there has been an elevation of most of the rocks. Snake Mountain rises boldly from a plain, seven miles from Lake Champlain, and is 1220 feet above the lake, and 1310 feet above the ocean. Its elevation at the highest part, as shown by this section, is greater by three hundred feet than it would have been originally.

Fig. 167.



Section of Snake Mountain, Addison.

Explanations.

a Calciferous sandrock; dip 10° E.
b Chazy limestone; dip from 10°–20° E.
c Trenton limestone, dip 25° E. The same rock west of the fracture dips less.
d Utica slate; dip 35° E.
e Hudson River slates; dip from 25°–35° E.
f Hudson River limestone.
g Red sandrock; dip 10°–20° E.
h Eolian limestone.
i Cranberry meadow over liquid peat.
k Debris from Oneida conglomerate.
m m Fractures.

This elevation has its maximum east of G. Willmarth's house. It gradually slopes to the south, and in Bridport the red sandstone is no higher than the surrounding country, as much as eight hundred feet below the summit in Addison. North of Addison, the rock that forms the summit at Snake Mountain is at the level of Otter Creek on the town line between Addison and New Haven, but it caps a series of hills between Addison and Missisco Bay. But it must be understood that originally, before the agents of erosion had plied these old formations, the mountain was continuous at the same level from Bridport (south part) to its northern limit, at its western outcrop; the whole dipping to the east. Some portions have been worn away more readily than others; hence the hasty observer, who may have thought that these great differences of level of the sandstone indicated great undulations in the strata, must see that the difference in level has been caused chiefly by erosion. The color representing the red sandrock upon the Geological Map shows the shape of the mountain and the range; and indicates where the edges of the range have been bitten into, as it were, by erosion; and the height lowered in a corresponding degree. At Snake Mountain there has been less erosion than elsewhere in the vicinity, for it extends furthest to the west, and is the highest portion of the range.

The west side of the mountain presents for two miles a nearly perpendicular face. The section passes through the northern part of the mountain, but we have represented one fact upon it, not on the immediate line. Commencing at the west end, we find shaly Trenton limestone upon the plain, according to Prof. Emmons, and a part of the same range precisely is seen further to the north on the Vergennes road, with an easterly dip. We next find the calciferous sandstone at R. Hank's house, in Addison, at the foot of the mountain, dipping east. Hence we have the Trenton limestone dipping apparently beneath the calciferous. This unnatural position is evidently produced by a dislocation. The calciferous sandrock has been elevated by some cause to the height of the Trenton limestone, and as a consequence has lifted up with itself all the rocks that were upon its back. Hence the origin of the present altitude of Snake Mountain. The calciferous sandrock here is a bluish gray limerock, with rather more lime than sand in its composition. Next occurs the chazy limestone, *b* (Fig. 167), exhibiting its characteristic fossil, the *Maclurea magna*, near Mr. S. W. Smith's house, upon the road nearest the mountain. This rock differs very little from the calciferous sandrock in its appearance. The Trenton limestone, *c*, is found just east of the chazy in the hill, where we obtained the *Trinucleus concentricus*, a characteristic fossil. This group can be traced both north and south a great distance. Its character upon the section is quite slaty—rather more so than usual. Between the Utica slate, *d*, and Hudson River slate, *e*, we have not attempted to draw the line upon the section. Both rocks are a calcareous slate, with small beds of a black limestone interstratified with them, and occasionally branching veins of white calcite ramify among the black slates. The lower portion of the slates is seen at Truman Smith's house, and nearly the whole of the slate may be seen by climbing the northwest corner of the mountain in the bed of a small brook. Most of these slates along the west side of the mountain are covered by soil and debris from the rocks above. Further south they appear near the house of Jesse Crane, 2d, in the northeast corner of Bridport, and west of Cobble Hill, near the south line of Addison. The upper member of the Hudson River group, is not seen at the northwest corner of the mountain. It is a curious silicious limestone, *f*, almost destitute of stratification, occurring in beds that taper to nothing almost abruptly. For instance, there is none of it on the line of the section, but less than a mile south of it, at Cobble Hill, is nearly one hundred feet thick. This hill is capped by it; and it may be seen upon the carriage road to the top of Snake Mountain from the west side. It is continuous from this point into Bridport and is quite thick. At Otter Creek, between Addison and New Haven, it occurs in limited quantity also.

The occurrence of this limestone has been perplexing to many who have tried to follow the published sections describing this mountain, because it was not mentioned in any of them, though it must have been seen by the authors of the sections. We think it satisfactorily shown elsewhere in this Report, that it constitutes the upper portion of the Hudson River group—as it is everywhere either above the slate or near the top. At Snake Mountain it is entirely above the slates, adjoining the red sandrocks, *g*.

Prof. Adams found graptolites in these slate rocks, which are now destroyed by fire. We were unable to discover their locality, but cannot doubt that they exist here.

The upper part of the slates, where the limestone does not appear, contain fragments of grit and small layers of sandstone. A sketch of the appearance of the mixed rock is given in Fig. 22. These irregular alternations continue for ten or fifteen feet when the sandstone or grit appears without any mixture of slate. This mass of grit is what was termed *graywacke* by old geologists. Of this, some portions are brecciated, belonging to the variety called *rubble* by Prof. Eaton, one of the earliest of American geologists.

The usual color of this red sandrock is reddish brown, and gray. The proportion of lime in it varies exceedingly, and the character of the rock often changes abruptly in the same stratum. As a general fact, the lower portion of it is calcareous, the middle silicious, and the upper part calcareous, gradually passing into the pure Eolian limestones to the eastward. Specimens of the mottled limestone or dolomite, called the Winooski limestone, occur also at Snake Mountain.

There is a peculiar reddish yellow color in the upper rock as it decomposes, that to a practiced eye distinguishes it from everything else. The rock derives much of this color from the peroxyd of iron. It may be seen by one riding along the road nearest the mountain and examining carefully the appearance of the upper rock. This color distinguishes it particularly from the calciferous sandrock, with which it has been confounded.

If we pass over the top of Snake Mountain and descend its eastern slope, we pass over a cranberry meadow underlaid by liquid peat, and observe many interesting drift striæ. At Otter Creek the sandstone passes under the surface, and the next rock upon the east is the eolian limestone *h*, apparently overlying the former. The junction is not seen, but the two rocks have been found almost in union three miles north in New Haven.

A similar section may be drawn, with the exception of the calciferous sandrock, at any place in the range between Bridport (south part) and Charlotte; and the junction of the Hudson River group with the red sandrock may be seen much further, even to Canada.

Prof. Emmons says that the fracture at the base of the mountain is "one of the most interesting and remarkable of all the geological phenomena disclosed during the New York survey." It can be followed from the north part of Bridport to Vergennes. Beyond these limits we hesitate to prolong it. It seems gradually to die out at both extremities, having its maximum in the section. Upon the figure the magnitude of the elevation is indicated by the line *m m*, a dotted line showing the base of the present bed before the action of erosion upon it.

Prof. Emmons now supposes that in addition to the fault described there is another fault at *d*, and that there is no rock present higher than the Trenton limestone; but that the slates are all older than the silurian, being the uppermost member of the taconic system, namely, the black slate. We cannot discuss this subject here, but will simply state one point relating to the discussion which is derived from this section.

To suppose the black slate to be taconic makes it necessary to regard the cap rock of the section, *g*, the same as the calciferous sandrock *a*, at the bottom of the mountain.—But they differ in two important respects. First lithologically, *a* is a limestone brownish and decomposing black; *g* is a variable rock, sometimes pure sandstone and then a mixture of sandstone and dolomite. Besides it is generally red, and decomposes reddish yellow. Its physical structure is different. Perhaps metamorphism would be adequate to explain the difference of the lithological character. But, secondly, the lower bed contains *Maclurea matutina*, while the upper bed contains no fossils whatever, except obscure fucoids. There does not seem to have been a sufficient metamorphosis of the red sandrock to obliterate so distinct a fossil as a Maclurea, if it ever existed.

The evidence for the fault is not clear. If it was necessary to regard the red sandrock as lower silurian, we should much prefer to regard it as the overlap of a great fold, pushed so far that it covers a much higher rock. But this question is discussed elsewhere at great length, in this Report. Nos. $\frac{8}{84}$ to $\frac{8}{118}$ illustrate the Snake Mountain section in the Cabinet. We proceed now to describe in detail the successive members of the lower silurian system.

POTSDAM SANDSTONE.

It was stated by Prof. Adams in his second Report, that this rock did not occur in Vermont. A careful examination, however, has satisfied us, that to a limited extent it may be found. Its lithological characters vary very little. In consequence of a metamorphic action, we reckon three varieties:

1. Pure Silicious Sandstone.
2. Hornblende Schist.
3. Gneiss.

The first of the three is what is universally known as the *Potsdam sandstone*, a hard, compact, thick-bedded sandstone, and perfectly homogeneous in structure, unless metamorphosed. Its color is generally white, in the eastern part of North America; it being red upon the shores of Lake Superior. The common variety may be seen in great perfection upon the hill overlooking the town of Whitehall upon the east. Nos. $\frac{6}{132}$ and $\frac{6}{133}$ in the Cabinet, represent the unchanged variety from Whitehall. No. $\frac{6}{131}$ is the same variety from West Haven of a red color. In small quantities the former occurs in Vermont, in West Haven, and upon Mount Independence, in Orwell.

The second variety (Nos. $\frac{6}{125}$ and $\frac{6}{126}$) cannot be distinguished from the hornblende schist which occurs among the azoic rocks of Vermont and New York. The specimens were obtained from the extreme south part of West Haven, in the upper part of the formation. It is not found in distinct beds, but is scattered in patches through the hill.

The third variety very closely resembles the laurentian gneiss. It seems to pass into it by insensible gradations. The specimens obtained (Nos. $\frac{6}{129}$ to $\frac{6}{131}$), are from the southwest part of West Haven. All the constituents of this rock are very small, and occasionally the feldspar or the mica may be wanting. These hornblende schists and gneissrocks indicate that a change has passed over a part of the Potsdam sandstone, analogous to that metamorphism that has so obscured the rocks of Eastern Vermont; for such rocks as gneiss, etc., are not formed except by the crystallization of the constituent minerals after the accumulation of the sediments.

Associated with these crystalline schists are veins of granite; whose feldspar is Labradorite, (Nos. $\frac{6}{122}$ and $\frac{6}{123}$.) This mineral is mostly confined to rocks below the silurian system; and in West Haven it extends only a few feet into the base of the silurian, and that in small veins from three to ten inches in width.

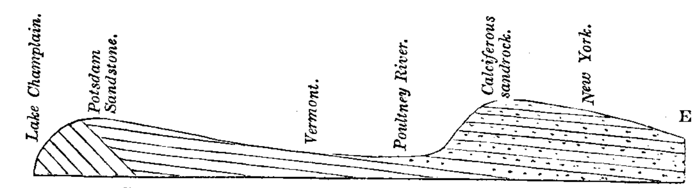
STRIKE AND DIP.

Locality.	*Strike.*	*Dip.*	*Observer.*
Whitehall, N. Y.,	N. 20° E.,	10° E.,	Prof. Mather.
West Haven, southwest part,	N. 10° E.,	8° E.,	C. H. H. and E. H., jr.
West Haven, west part,	East of north,	4°–5° E.,	C. H. H. and A. D. H.
Orwell, Mt. Independence,	East of north,	4° E.,	C. H. H.
Ticonderoga, N. Y.,		10° N.E.,	C. H. H.
Shoreham, east part,	N. 10° E.,	14° E.,	C. H. H.

The unconformability of the dip of this rock to the Laurentian beneath, may be seen at the extreme southern point of West Haven. Upon the lake opposite to the termination of

the railroad the dip of the older rock is 36° E, and only a few rods east the dip of the sandstone is only 9° E. As the south point of West Haven terminates in a cliff, this section can be distinctly seen from quite a distance. The rock with the greater dip is as distinctly quartz rock as the other, and there is also a large ledge of quartz rock upon the west side of Lake Champlain with the same inclination. Hence the sudden change in the dip is to be regarded as a safer distinction between the silurian and Laurentian series, than a difference of lithological character.

Fig. 168.



Section across West Haven, Vt., and Whitehall, N. Y.

This change of dip is represented in the annexed figure (Fig. 168.) It passes through the south end of West Haven, a mile north of the town of Whitehall, and hence the east part of the section, showing the calciferous sandrock, is in New York.

Range, Extent and Thickness.

There are three different localities in which this formation occurs in Vermont: in West Haven, Orwell, and the east part of Shoreham. In West Haven it may be traced about three miles, from the mouth of Poultney River, to the north, when it either thins out entirely, or passes under the next rock above. It is not seen in New York between Whitehall and Ticonderoga, upon the west side of Lake Champlain: hence, as it appears in Vermont nowhere between West Haven and Mount Independence, it is probable that it may be found beneath the calciferous sandrock, the whole of this distance about eighteen miles. At Mount Independence it is hardly consequential enough for the map; as it occupies twenty or thirty feet of altitude at the base of this mountain, and extends about a quarter of a mile north and south, upon the edge of Lake Champlain. From thence it crosses the lake to Ticonderoga, where it is much thicker.

The Potsdam (?) sandstone in Shoreham is of limited extent. It is less than two miles in length, and an eighth of a mile in width, and it is perhaps thirty or forty feet thick. It was first pointed out by Prof. Emmons. There are no fossils in it to determine its age, but the limestone overlying it is said to have a lower silurian maclurea in it. It must have been elevated to its present position subsequently to its formation, as the first rock west of it belongs to the Hudson River Group.

The thickness of the Potsdam sandstone at Whitehall is stated by Prof. Mather to be from one hundred and fifty to two hundred feet. It thins out rapidly as it passes northward, though not as suddenly as some have stated. There must be about fifty feet of thickness as it enters Vermont; and to the north it passes beneath the calciferous sandrock, so that its thickness beneath the latter is not known. Most of this formation in West Haven is concealed by overlying clay. The only mineral in the State Cabinet from this rock is Labradorite.

Fossils. No organic remains of positive character have been discovered in the Potsdam sandstone in Vermont. The best characterized species of the group, found near by, in New York, are the *Scolithus linearis* (Hall), *Lingula prima* (Con.), *L. antiqua* (Hall), and *Conocephalites minutus* (Bradley.)

In Iowa, Prof. Owen has described from the Potsdam sandstone, five species of *Dikelocephalus.*

The most important of all these fossils, are the two genera of trilobites, *Conocephalites* and *Dikelocephalus*, because in Bohemia, England and Spain, these forms of life are found in the very oldest fossiliferous strata. In Bohemia the strata are said to belong to the "Primordial Zone of Life;" and in England, by the Government Geologists, to the "Lingula Flags." It seems then the opinion, expressed by eminent naturalists in this country years ago, is confirmed by the recent discovery of these trilobites, viz: that in the Potsdam sandstone are found the remains of the oldest inhabitants of North America. It is certainly very singular, that in the lithological character and thickness of the strata, there should exist such great differences upon the two sides of the Atlantic Ocean. There are, however, series of strata in Eastern Massachusetts and elsewhere on the coast, containing the *Paradoxides Harlani*, another characteristic fossil of the primordial zone of life, which agree more nearly with the European groups. And there is a very warm discussion being carried on at this time respecting the age of certain rocks in Vermont, which are referred to the primordial zone of life by eminent authorities. In another part of this Report both parties in this discussion speak for themselves.

Some geologists have considered the *Scolithus linearis* as a characteristic fossil of the Potsdam sandstone, and have pronounced certain belts of rock to be of this age from its presence in them. This fossil is found in great abundance in Vermont, in the quartz rock at the western base of the Green Mountain range. If the early opinion of the Scolithus is correct, then the determination of the age of the quartz rock would be easy. But for various reasons, which are stated elsewhere, we do not regard this fossil as necessarily characteristic of the Potsdam sandstone.

CALCIFEROUS SANDROCK.

This is the second rock overlying the Laurentian series, and there is considerable thickness and extent of it in Vermont.

Lithological Characters.

The prevailing character of this rock is that of a sandy limestone, compact and thick-bedded. There are several varieties, which we will mention in no determinate orders, as we have measured no careful section of this formation.

1. The Common Sandy Limestone.
2. Geodiferous Strata.
3. Light Colored Limestone.
4. Brecciated Limestone.
5. Pure Quartz Sandstone.
6. Clay Slate.
7. Fucoidal Layer.

The first variety is very common. Most of the specimens are of this description — for example, Nos. $\frac{6}{117}$, $\frac{7}{175}$ to $\frac{7}{181}$, etc. This rock forms the transition from pure sandstone to pure limestone, and therefore partakes of the character of each. Generally the sand predominates. Very frequently these strata contain geodic masses of quartz and calcite, and also chert. These form the second variety. They invariably give off a fetid smell when broken. Wherever the first variety occurs the second generally accompanies it. Occasionally small masses of bituminous matter fill little seams and cavities of this rock, and in some cases where it is disseminated in minute particles it imparts a dark color to it. The geodic quartz and calcite, though generally white, are sometimes black, as in No. $\frac{6}{116}$. Some of these varieties have a red surface, as in No. $\frac{6}{115}$, where it is very bright, and may perhaps result from small ferruginous concretions resembling fucoids.

Occasionally there are quite thick beds of a very pure drab-colored limestone (the third variety) in the upper part of this formation, resembling the limestone of the birdseye series. It is particularly abundant on the east shore of Lake Champlain in the southwest part of Orwell, and the northwest part of Benson. They are Nos. $\frac{6}{146}$ to $\frac{6}{149}$.

In the upper part of this rock there is a brecciated limestone. The fragments are never more than an inch in length, and the variety resembles breccias in the Chazy and Devonian limestones. It is not common in the calciferous sandstone. The specimens of it in the State Cabinet, are Nos. $\frac{6}{113}$ and $\frac{6}{141}$, from West Haven and Orwell.

It is not unusual to find beds of pure silicious sandstone interstratified with the limestones, and in lithological character it cannot be distinguished from the Potsdam sandstone. These beds are the most abundant in the lower members of the calciferous group, and may be seen in Vermont, both in the east and west parts of West Haven (No. $\frac{6}{119}$), and in the east part of Shoreham. They vary in thickness from a few inches to twenty feet.

There is a peculiar variety of this rock quite well developed along the shore of Lake Champlain for twenty miles below Whitehall. It is a clay slate, somewhat calcareous. It reminds one rather of the slates and shales of the silurian rocks in Europe, than of the sandstones and limestones of this age usual in North America. There are many fucoidal (?) markings upon them, and the specimens ring like iron when struck with a hammer. It was noticed first upon the south side of Larrabee's Point in Shoreham, and it was so near the *Maclurea magna*, that we then supposed it to belong to the Chazy limestone. We have found no distinct fossils in it; and have placed it in the calciferous group because it is generally associated with its sandy and drab-colored limestones, and is always below characteristic fossils of the Chazy. One mile south of Chipman's Landing, in Orwell, this slate may be found with a glazed surface. The thickness of it at this point is about seventy feet. For two miles this slate may be seen along the lake shore, in the south part of Orwell. Its calcareous character is evidenced by numerous deposits of calcareous tufa at its base.

The sixth and last variety is represented by a large specimen in the Cabinet from Mount Independence, a part of which is represented in Fig. 170. It was supposed to belong to the Potsdam sandstone, until a drop of acid revealed a small percentage of carbonate of lime in its composition. Its position agrees exactly with the fucoidal layer described by Prof. Emmons in his Report on the Geology of the second district of New York, pages 270, 271. He rarely found it more than fifteen feet thick, and it was invariably found at the base of the calciferous. The most southern extremity of it in New York is at Crown Point, eleven miles north of its location in Vermont, at Mount Independence. Its thickness at this place cannot be more than eight or ten feet.

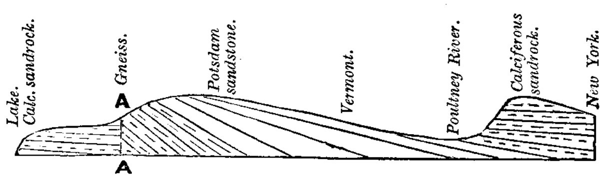
STRIKE AND DIP.

Locality.	*Strike.*	*Cleavage.*	*Dip.*	*Observer.*
Whitehall, N. Y.,	N. and S.,		5° E.,	E. H., jr. and A. D. H.
West Haven, south part,	N. 10° E.,		10° E.,	E. H., jr. and A. D. H.
West Haven, west part,	N. 10° E.,		5° E.,	C. H. H.
West Haven, southwest part,			3° E.,	C. H. H.
Benson, west shore,			7° E.,	C. H. H. and A. D. H.
Benson, northwest corner,			8°–15° E.,	A. D. H.

Orwell, southwest corner,			10° W.,	A. D. H.
Orwell, southwest part,	East of north,	80° E.,	10° E.,	A. D. H.
Orwell, Chipman's Landing,	N. 70° E.,		25° N.,	C. H. H.
Orwell, Mt. Independence,			5° N.,	C. H. H.
Orwell, Mt. Independence,			4° N. E.,	C. H. H.
Orwell, northwest of center,	N. 7° W.,		35° E.,	C. B. A.
Orwell, center,			5° E.,	C. H. H.
Shoreham, southwest part,	N. 70° E.,		10° N. W.,	C. H. H. and A. D. H.
Shoreham, southwest part,	About E. and W.,		12° N.,	C. H. H.
Shoreham, east part,			General dip to east,	C. H. H.
Addison, near Snake Mountain,	About N. E. & S. W.,		15° E.,	C. H. H.
Addison, Snake Mountain,			10° E.,	C. B. A.
Panton, east part, (?)			4°–5° E.,	C. H. H.
Panton, west part, (?)	N. and S.,		15° E.,	C. H. H. and A. D. H.

The position of the calciferous sandrock as indicated by this table, is very plain. It occupies the *upper part of the valley of Lake Champlain, and as a part of the second concentric circle about the gneistic nucleus of northern New York, it dips away from it to the east. It has been disturbed very little since its formation as indicated by the small inclination of its beds. Sometimes there is an exceptional northerly or westerly dip. The first is in consequence of a curve in the whole formation; and the latter is probably a local exception.

FIG. 169.



Section across West Haven, Vt. and Whitehall, N. Y.

At West Haven this rock is found both upon the east and west sides of older rocks, with an easterly dip in both cases. To account for this we must suppose that the older rocks upon the east have been elevated, probably since the formation of the calciferous. The junction, represented by theline A, A, in Fig. 169, may be seen near the south end of West Haven. The same position of the three rocks may be traced for three miles to the north.

The older rocks at the northern extremity of the uplift gradually sink down and when out of sight are covered up by the calciferous sandrock dipping east.

Plicated rocks, supposed to be strata of calciferous sandrock, are found in the east part of Shoreham. The deepest valley is at Newell's Mill, where numerous specimens of an Euomphaloid shell may be obtained. The strata are mostly thick-bedded, and often between them are thin sheets of argillaceous matter, associated with bituminous fragments. The number of folds in this limestone even exceeds those in the red sandrock series, in Monkton and Hinesburgh.

Range, Extent and Thickness.

There are four different ranges of this deposit. The most extensive extends from West Haven to Larrabee's Point, after which it passes into New York, and there extends with occasional interruptions to Canada, along the west side of the lake. Its length in Vermont is twenty miles, and its width from a few rods to three miles. Another range is in the east part of Shoreham, where it has been elevated to the level of the red sandrock at least. This range is not very extensive. A longer belt of it lies west of Snake Mountain, extending from the middle and south part of Addison to the north part of Panton, near Vergennes. It is mostly concealed by the overlying deposits of Champlain clays. A fourth locality of this rock is in the west part of Panton, where there seems to be a range a few rods wide and less than a mile in length, underlying the Chazy limestone.

Commencing at Whitehall, N. Y., we will trace the first range of calciferous sandrock as it extends northwardly, chiefly along the banks of Lake Champlain. At Whitehall this rock forms the upper part of the mountain east of the village. It is found proceeding northwards, east of Poultney River, and it enters Vermont south of the mouth of Codman's Creek in West Haven. In the northwest part of West Haven

* The south is the *upper*, and the north the *lower* part of Lake Champlain.

it unites with a spur that runs up to the very southern extremity of the town, upon the east shore of Lake Champlain. This spur, represented upon Figs. 168 and 170, contains many beds of sandstone more than the average.

The southern prolongation of West Haven contains three different rocks, as already mentioned. Along the west edge of this promontory there is quite a high range of hills, the highest of which is called Bald Mountain. The rise from the west part of West Haven to the top of Bald Mountain is very gradual. The north side of the highest peak is precipitous, but the range is not entirely cut off, for the hill still continuing, terminates abruptly at the mouth of Poultney River. This countour of surface is due, not to drift, but to the nature of the rocks, and perhaps elevation. The base of the highest summit is occupied by gneiss, the oldest rock, the others probably overlying it. The abrupt southern slope of Bald Mountain is probably connected with the elevation of the gneiss; as the western side, which is precipitous, certainly is. The range of hills is finally cut through at Whitehall by Poultney River, which made its way over the more easily decomposing limestone as far as possible.

Lake Champlain has cut a channel for itself through the calciferous sandrock for twenty miles, sometimes three hundred feet deep. Occasionally the gap is only just wide enough to allow the passage of the steamboats, as at the narrows near the northwest corner of West Haven. The formation covers less width of surface in the north part of West Haven, and in Benson,—the height compensating for the width. The southwest part of Benson, upon this rock, is mostly uncultivated, on account of its steep hills, and deep narrow ravines. The staid uniformity of the limestone is broken at the northwest part of Benson by the appearance of the drab colored variety, extending a quarter of a mile along the shore. With it there is at length associated the ordinary limestone; this presently gives way to the slaty variety, which extends two miles along the shore, into Orwell, one mile south of Chipman's Point. Here the ledge is eighty feet high, made up of a black glazed slate, from the decomposition of which calcareous tufa is constantly forming.

The eastern boundary of the calciferous sandrock is about two and a half miles east of Benson landing. Its western boundary reaches the base of the formation in Vermont only at the west foot of Mt. Independence, in Orwell. There it is underlaid by a few feet of Potsdam sandstone, and the opposite side of the lake is gneiss. At the southern extremity of Larrabee's Point in Shoreham the slate of the upper portion of this rock may be seen upon the eastern side. It is exposed there in two low cliffs, that may be reached by a boat. The dip is north, and the formation here bends westward, and crosses the lake to Ticonderoga, N. Y.

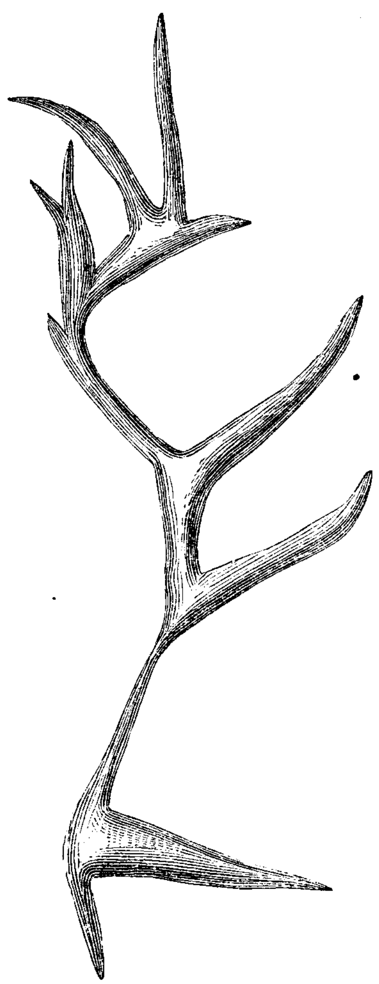
It is much thinner in Ticonderoga and Crown Point than in Vermont, and at Port Henry it is seen for the last time, before its plunge under the lake. Here it is only a few feet thick. It re-appears two and a half miles south of Westport, and extends for three miles, when it again passes under the lake. At Split Rock it again appears, and extends far enough east to include perhaps one of the islands belonging to Vermont, and the extreme end of the point adjacent. It continues from Split Rock to Clinton Co., N. Y., but in very limited amount. At Plattsburg it begins to expand in breadth and thickness, reaching its maximum in Canada, after which it passes southwesterly back into New York.

The calciferous sandrock in the east parts of Orwell and Shoreham is elevated into an unnatural position. At Orwell village it shows itself prominently, and is characterized by its thick beds and geodiferous masses. One and a half miles northwest of the village Prof. Adams found, according to his note book, "abundant fragments of trilobites and a small species of Maclurea" of this age. This rock shows itself upon the line between Orwell and Shoreham, appearing there as a white metamorphic thick-bedded limestone. The same rock appears directly east of Shoreham Center. At Rich's Mills in Shoreham, it is associated with beds of sandstone twenty feet thick. At Newell's Mill in Shoreham, there are numerous fossils of the genus maclurea and ophilata present in it. Between these two mills the characteristic variety of this rock is well shown upon the west side of a large hill, by the side of the road. There is a deep gorge in the vicinity, excavated in this rock by the Lemonfair River. Immediately east of the sandstone, west of Newell's Mills, this rock shows itself in great force. In this region there are several undulations, which have not been traced north and south a great way, and they are probably local. To this formation belongs the ledge of sparry limestone at Birchard's saw mill, a great ledge fifty feet high with a perpendicular western wall upon the east side of the Lemonfair; also the ledge of limestone with a westerly dip near H. DeLong's house—both in the northeast part of Shoreham. As this rock joins upon the metamorphic limestones to the east, its eastern boundaries have not been ascertained with accuracy; especially as the true place of the latter upon the geological scale was not made certain till after the completion of the field work of this region.

In the south part of Addison commences the third range of calciferous sandrock. It is seen in place at the west foot of Snake Mountain, dipping from 10°—15° E. It is composed of two varieties, the lower layer is quite silicious and the upper layers are thick-bedded like the Chazy limestone at Vergennes. The amount of the whole is inconsiderable. We have found the calciferous sandrock in place nowhere else, except near the Elgin Spring, in Panton, where it closely resembles the Potsdam sandstone, so much silica is there in its composition. The rock dips slightly to the east.

These ledges are situated upon a sort of table land, about 250 feet above Lake Champlain. The village of Addison is upon the same elevation. As the rocks in this vicinity are almost entirely covered with clay, it is difficult to determine the boundaries of the various formations. If there is an uplift of all the lower silurian rocks west of Snake Mountain, the west edge of this terrace is the western limit of the calciferous. If not, then this rock probably extends one or two miles westward. Its northern limit is ascertained to be south of Vergennes.

Fig. 170.



Palæophycus.

In the west part of Panton, the amount of the formation is very small, not sufficient for the map. It deserves notice, because it indicates that small disturbances among these lower silurian rocks are quite common.

The thickness of the calciferous sandrock in Vermont was estimated at 300 feet, by Prof. Adams. We should estimate the thickness the same. This corresponds with its general thickness in New York.

The minerals are not numerous in this member. Occasionally good specimens of different colored calcites, in different crystals of transparent and fetid quartz and fragments of bituminous coal, occur in it in Vermont.

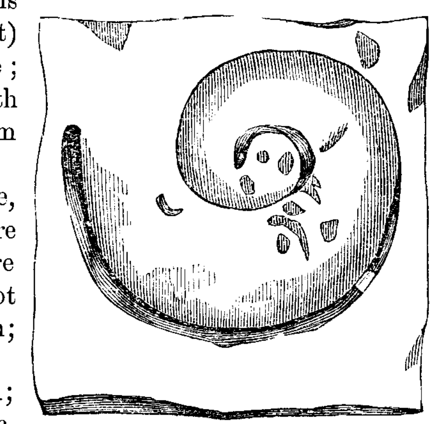
Fossils. Quite a large mumber of species of fossils have been found in the calciferous sandrock in North America. We have collected for the State Cabinet, from Vermont, only four or five species of organic remains, concerning which we can speak with confidence. They are a species of *Palæophycus*, *Maclurea matutina* (Hall), *M. Sordida* (Hall), and a species of *Ophileta.*

Fig. 170 represents, poorly, a part of a large specimen of a species of Palæophycus from the fucoidal layer at Mount Independence, in Orwell. Its position therefore, is at the base of the calciferous sandrock. The stone is terete, simple or branched, cylindric or subcylindric; the surface is nearly smooth, without transverse ridges, and was apparently hollow. These plants and others like them, scattered through this rock, are undoubtedly marine. They seem to have been large, succulent stems, perhaps hollow, like certain algæ.

It is common to find other traces of plants in the calciferous sandrock in Vermont, in the occurrence of numerous small bunches of bituminous matter. Of course it is impossible to derive, from these fragments, any specific information relating even to the generic character of the plants from which the bituminous matter was derived. So abundant is this vegetable matter in some localities as to impart a nearly black color to the rock.

The genus maclurea is not found higher than the Trenton limestone, and is therefore characteristic of the lowest beds of the lower silurian. It is a nucleobranchiate mollusk, and is most nearly allied to the family Atlantidæ. The following is Woodward's description of the genus. "Shell discoidal, few whorled, reversed (the apical whorls being brought down to the base and the umbilicous flattened out) upper surface convex, deeply perforated instead of raised into a spire; outer side spirally grooved; operculum sinistrally sub-spiral, solid, with two internal projections for the attachment of muscles—one of them beneath the nucleus, and very thick and rugose."

Fig. 171.



Maclurea matutina.

Both species of the *Maclurea* in the calciferous sandrock are obscure, as they appear in Vermont, both from weathering and the rough nature of the matrix. Fig. 171 represents the *Maclurea matutina,* the more common form. This species is discoidal, involute; the spire is not elevated; the umbilicus is deep, and the surface is not certainly known; probably it is striated.

The *Maclurea sordida* has a discoidal shell; its spire is not elevated; the mouth is slightly expanded, and the surface is apparently smooth. The first of these species occurs at the east part of Snake Mountain in Addison, near Orwell Center, in Benson and West Haven. The other species probably occurs in connection with the preceding in several of these localities; but we found it best shown in a bowlder picked up in Pawlet, which had been transported several miles from its original position.

Ophileta. Observers have found species of this genus in Vermont, probably the *O. levata* Van. The generic (or sub-generic) character of *Ophileta* is the following: Discoidal; spire sunk above; umbilicus below perfectly open, and exposing the whorls all on one plane; whorls numerous; truncate and triangular exteriorly; mouth trigonal. Forms with deeply concave spires. The best authorities consider this subgenus as related to the beautiful living genus *Janthina.*

Geological Position and Equivalency.

All agree that the calciferous sandrock is at or near the base of the lower silurian, certainly the particular terrain which has just been described. But some geologists suppose that the red sandrock series is the same as the calciferous sandrock, and perhaps including the Potsdam sandstone. We give elsewhere our views upon this subject; and will simply say here that in case of the reference of the red sandrock series to the lower silurian, the conjectural range of calciferous sandrock in Shoreham and Orwell, already described, with the accompanying conjectural Potsdam sandstone, is a part of the range of red sandrock, though different to an external view. It is just such a change as metamorphism might produce.

We will mention a few localities of rocks which are represented as red sandrock upon the map, but which are the same rock as the exposure at Newell's Mill in Shoreham. At Mr. De Long's house in the northeast part of Shoreham, there are exposures of limestone with a strike of N. 10°–20° E. and dipping 45°–72° W. This position is unusual, and is probably local. At Lemonfair River, a short distance west of the foregoing, is a precipitous ledge of a calciferous sandstone dipping 2° E. At Birchard's Sawmill still further west, the rock runs N. 10° E, and dips 15° E. In the northeast corner of Shoreham, there are three systems of joints in these rocks. N. 45° E., dip 65° E; N. 65° W., perpendicular; and N. 45° W., dip 75° W.

CHAZY LIMESTONE.

Prof. Adams, in his second Annual Report upon the Geology of Vermont, p. 164, used the term *Isle La Motte limestone* to include what we describe in this Report under the names of Chazy limestone, birdseye limestone, and Black River limestone. We have represented the extent of all three of these formations upon the Geological Map, Plate I, by the same color, because the extent of the birdseye limestone and the Black River limestone is too insignificant to deserve a separate delineation.

The name of the Chazy limestone is derived from the town of Chazy, Clinton County, New York, where it is clearly developed.

Lithological Characters of the Chazy Limestone.

The general character of this rock is that of a dark-colored, irregular, thick-bedded limestone. The varieties of the formation in Vermont are all limestones. They are

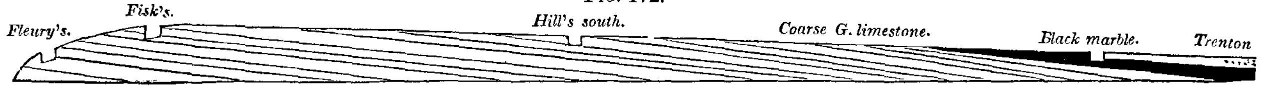
1. Thick-bedded, Dusky-colored Limestone.
2. Limestone containing Chert and Grains of Sand.
3. Encrinal Limestone.
4. Concretionary Limestone.
5. Brecciated Limestone.

We have an approximate section of some of these varieties as they occur upon the Isle La Motte, which we will give in the descending order. First, below the Trenton Group is a schistose limestone, filled with small corals. Next comes the black or Isle La Motte marble (the Black River limestone), as shown at Hill's north quarry. The marble is twelve feet thick. Southwest of this quarry is Hill's south quarry, known formerly as Cook's quarry. Between the two quarries there is a great thickness of coarse gray limestone containing a great many corals, fragments of trilobites, maclureas, etc. In many places the rock is composed of nothing but fossils. Hill's south quarry is composed of several layers. First, in the order of descent, is a limestone unsuitable for quarrying, containing large Orthocerata; secondly, beds of the marble, containing multitudes of maclureas, and comminuted corals; thirdly, a stratum two feet thick of compact gray limestone; fourthly, thick beds of very compact limestone, mostly consisting of comminuted fragments of corals, with encrinites, etc. Below this quarry, coarse gray thick-bedded limestone extends to Fisk's quarry, in the southwest portion of the island. Numerous specimens of the *Maclurea magna*, the characteristic fossil of this group, show themselves upon almost every ledge over this interval. There are forty or fifty feet of thickness of building stone in Fisk's quarry.

These strata are all a dark gray compact limestone, ranging slightly in color, texture, hardness, etc. Below the quarry we noticed before reaching the water's edge, a thick black stratum, a gray tough limestone, a red encrinal limestone with occasional white patches, and an unknown thickness of slaty layers passing under the lake. Fleury's quarry appears to lie under Fisk's, but we did not examine its bed. Below this quarry, at the water's edge, we measured the following strata:

Limestone in shaly masses, four feet; stratum of compact limestone, two feet; concretionary limestone, fifteen inches; limestone stratum, six inches; shaly limestone, two feet; very compact limestone, twelve inches; slaty limestone, six inches. Tough compact limestone; containing *Maclurea magna* seven inches in diameter, occupied the rest of the way to the water's edge (a few inches.) This is not the bottom of the chazy limestone, as the same fossils are found at Point au Roche, N. Y., west of Isle La Motte, with an easterly dip.

Fig. 172.



Section of Chazy Limestone across Isle La Motte.

Fig. 172 represents a section of the Chazy limestone upon this island, overlaid by Trenton limestone. The position of the different quarries is indicated by gaps in the section, and the overlying strata of Trenton limestone are next above the heavy black line on the right hand of the section. The section runs in a northeast and southwest direction across the upper part of the island. A map of this island is given in Plate VIII, Fig. 3, and a description of it will presently be offered.

We will add a few words respecting some of these lithological characters. The chert, abundant in the second variety, is very prominent near Basin Harbor in Ferrisburgh. The chert being harder than the limestone is not so easily decomposed; and hence it appears in irregular forms, sometimes drawn out into long curls, projecting along the line of strike. They are thus seen to be confined to particular layers. This chest and a few grains of sand are all the silicious matter contained in this group in Vermont, while elsewhere, as in Canada, strata of sandstone, like the Potsdam, are said to occur. It is not unlikely that the cherty masses indicate the former presence of fossils, and in some bunches a coralline structure is still evident. The brown earthy spots and geodes of quartz and calcite, found in the rock below, are entirely wanting in this rock.

The third variety—encrinal limestone—is designed to specify a red mass of encrinital stems found below Fisk's quarry on Isle La Motte, where it was discovered by Prof. Thompson. It is red and white, and much resembles the beautiful encrinal limestone of Lockport, N. Y. Large bowlders of this variety are found in the north part of North Hero, which probably originated from this locality. We have noticed this variety no where else. The stratum is nearly three feet thick. The specimens of it in the Cabinet are Nos. $\frac{11}{269}$, $\frac{11}{270}$ and $\frac{12}{194}$.

We have noticed the concretionary variety at several localities, particularly at the south end of Isle La Motte, and in the west part of Panton. The concretions vary in size from a pin's head to spherical masses from one to two inches in diameter. Some are spherical, others are elongated. All resemble small pebbles, and it was only a careful examination that showed us that this variety, in some of its forms was not a sandstone cemented by carbonate of lime. They are Nos. $\frac{8}{145}$ to $\frac{8}{149}$.

Specimens of brecciated limestone belonging to this rock occur in the west parts of Ferrisburgh and Panton. It may be regarded as a conglomerate, formed from the ruins of the calciferous sandrock. The fragments are occasionally rounded.

At the south end of Isle La Motte, there are a great abundance of *shrinkage cracks* or *sun cracks*. They were *mud veins*, originally, upon the shore of the silurian ocean, filling the cracks caused by the rapid drying of the mud by a tropical sun. More or less evidence of shore action can be traced upon most of the groups of the lower silurian in Vermont, and elsewhere, especially in the red sandstones about Burlington. These shrinkage cracks in the Chazy are quite large and extensive.

Divisional Planes. Cleavage planes are common in this rock. They are particularly noticeable in the north part of the lake. Usually they dip at right angles to the strata, even obscuring the strata, and they are generally the most prominent marks of division. We measured the following divisional planes:

On South Hero, at the middle of the west shore, the strata are nearly horizontal, and the cleavage seams are perpendicular; and their deviation does not vary much from north and south. The same planes were seen all over the island where this limestone occurs.

South Hero, west part, cleavage seam; strike N. 13°E.; dip 62°W.

South Hero, Merriam's Bay, cleavage seams; dip 25°E., and the strata 8° northerly.

Point au Roche, N. Y., cleavage seams; dip 58°E., and run N. 42°E.

In the west part of South Hero we measured several joints. The most common, and those that are found wherever the rock occurs, run N. 60° W., and are perpendicular. Another set run N. 10°W. with the same inclination. Perhaps the first observation given relates to joints rather than cleavage, but they are as abundant as strata seams.

At Isle La Motte the joints occur only at wide intervals; and those appear remarkably even and distinct, with a general east and west direction.

DIP AND STRIKE OF THE STRATA.

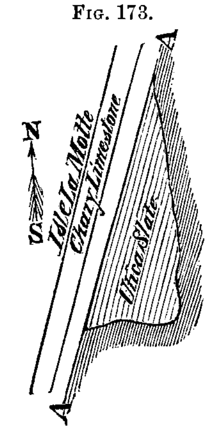
Locality.	*Strike.*	*Dip.*	*Observer.*
Larrabee's Point,	E. and W.,	12° N.,	C. B. A.
Larrabee's Point, south end,	E. and W.,	9° N.,	C. H. H.
Chimney Point, Addison,	N.E. and S.W.	8° N.W.,	C. H. H.
Crown Point, N. Y.,	N. 48° E.,	9° NW.,	C. H. H.
Bridport, west part,	N.E. and S.W.,	Anticlinal,	Wing.
Addison, Snake Mountain,	N. 46° E.,	25° E.,	C. H. H.
Addison, Snake Mountain,		10°–20° E.,	C. B. A.
Waltham,	N. 35° E.,	30° E.,	C. H. H.
Panton, west part,	East of north,	15° E.,	C. H. H.
Panton, Adams' Ferry,	N. 10° E.,	15° N.E.,	C. H. H. and A. D. H.
Vergennes,		Nearly horizontal,	C. H. H.
Ferrisburgh, west of Vergennes,		50° W.,	C. H. H.
Ferrisburgh, center,	N. 40° E.,	30° E.,	C. H. H.
Ferrisburgh, Button Bay Island,	N. 40° E.,	18° S.E.,	C. H. H.
Ferrisburgh, do.,	E. 20° S.	13° E.,	Z. T.
Ferrisburgh, between do. and Scotch Bonnet,		An arch,	Z. T.
Ferrisburgh, Basin Harbor,		Dip east,	C. H. H.
Ferrisburgh, west part,		15°–20° E.,	C. H. H.
Ferrisburgh, Island,		9° SE.,	C. H. H.
Ferrisburgh, half mile north of Basin Harbor,		7° E.,	Z. T.
Ferrisburgh, a mile north of Basin Harbor,		7° E.,	Z. T.
Ferrisburgh, northwest part,	About N.E. and S.W.,	12° S.E.,	C. H. H.
Thompson's Point,	do.,	8° SE.,	Z. T.
Butterfield's Island,		9° S. of E.,	Z. T.
Charlotte, do., extreme end,		Undulating,	Z. T.
Charlotte, east of lake,		Dip west,	Prof. Emmons.*
Valcour Island, N. Y.,	East of north,	5° E.,	C. H. H.
South Hero, Merriam's Bay,		8° N.,	C. H. H.

* Geology Second District, N. Y., page 281.

Providence Island,		40° N.,	C. B. A.
South Hero, McBride's Bay,		4°–5° E.,	C. H. H.
South Hero, near do.,	N. 22° E.,	6° E.,	C. B. A.
South Hero, Sawyer's Bay,		5° E.,	C. B. A.
Sister's Islands,		6° E.,	C. B. A. and C. H. H.
Point au Roche, N. Y.,	N. 42° E.,	12° SE.,	C. H. H.
Point au Roche, N. Y.,		12° NE.,	C. H. H.
Isle La Motte, south point,		5° NE.,	C. H. H.
Isle La Motte, Fisk's,		5° NE.,	C. H. H.
Isle La Motte, Fisk's,	About N. and S.,	5°–6° E.,	C. B. A.
Isle La Motte, southeast part,	N. 40° E.,	30° SE.,	C. H. H.
Isle La Motte, hills south of quarry,		5° NE.,	C. H. H.
Isle La Motte, do.,	N. 65° E.,	4°–5° NW.,	C. B. A.
Isle La Motte, north of do.,	N. 65° E.,	45° NW.,	C. H. H.
Isle La Motte, hills north of quarry (Black R. limestone),		5° NE.,	C. H. H.
Isle La Motte, do.,	N. and S.,	5° E. and 5° W.,	C. B. A.

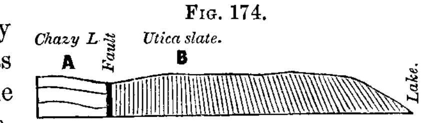
The general position of the Chazy limestone is that of a formation dipping at a small angle to the northeast and north. Numerous local exceptions to this rule are found. There is also an anticlinal, that may be traced from Crown Point in New York, across the lake to Chimney Point, thence northeasterly, through the towns of Addison, Panton and Ferrisburgh, into Charlotte. No more is seen of this rock except in the islands in the northern part of Lake Champlain, where the anticlinal is not observable, unless it be at Hill's south quarry in Isle La Motte. Here, there is a small anticlinal in the middle of the quarry. About midway between the docks at each of Hill's quarries on Isle La Motte, there is an irregularity in the dip, and when we examine the ledge we see that two different rocks have been brought into proximity by some disturbance. Fig. 173 represents the position of the slate and the limestone upon the borders of the lake. A, A, indicates the fault between the two. The position of the strata is represented in Fig. 174; from which it would appear that the Utica slate was depressed below the Trenton limestone, so as to be at the same level as the Chazy limestone. It is possible that the disturbance has destroyed the original marks of stratification in the slate, and that now, as in the upper part of the lake, the strata seams are obliterated. The area of the slate is about four square rods, and the smoothed side of the Chazy limestone may be traced several rods further with the direction of N. 20°E.

Fig. 173.



Junction of Chazy Limestone & Utica Slate.

Fig. 174.



Junction of Chazy Limestone and Utica Slate.

Two other facts indicate that this elevation extended along the whole of the east side of the island. About one-fourth of a mile north of Hill's black marble quarry, a similar conjunction of slate and limestone is seen, of about the same extent. The depression of the slate is less, because the limestone contiguous is Trenton limestone. Were we to regard the slate in its proper place, at the latter locality, it would give a thickness of only 25 feet to the Trenton, which we know to be certainly 200 feet thick on this island. Moreover the Trenton dips west, and the Utica slate dips east, at the junction of the two. As the limestone resists decomposition better than the slates, it is probable that the Utica slate of Alburgh and North Hero once filled up the lake between Isle La Motte and those points of land respectively. The depth of the lake east and west of Isle La Motte confirms this view: for it is very shallow upon the east side, and unusually deep upon the west side of the island. The depression, however, must have been much greater at the southern than at the northern extremity of the island.

The other fact showing disturbance upon this island, is seen at the southeast part. There the strata are all thrown about in various direction, like a gigantic breccia, and the rock is indurated and occasionally rendered crystalline and remarkably ferruginous. Clowk Island shows all these phenomena in perfection. This is a mass of coarse limestone, with very little soil, as we should judge in sailing past it. The west uniform dip of this rock on the principal island opposite to Clowk Island, is 30° N. E.—an unusually large dip for the Chazy limestone.

In the northwest part of Panton, at Adam's Ferry, there is another example of the conjunction of chazy limestone and Utica slate. We are inclined to think that all the Utica slate on the shore of the lake between Panton and Shoreham, is more or less disturbed by the same causes. North of Split Rock in New York, there is another case of the junction of slate and limestone, similar to the ones described here, according to Prof. Emmons' Report.*

Range, Extent and Thickness.

There is one principal range of the chazy limestones in Vermont, interrupted only by Lake Champlain. It has not been observed south of Benson, where Prof. Adams found it in the northwest part of the town, upon the land of Orrin Benson. Next it is seen upon Larrabee's Point in Shoreham, where there is a quarry of black marble. It is very thin in these two towns, while the calciferous sandrock beneath is very largely developed. Curving at Larrabee's Point, it crosses into New York, where it is abundantly seen at Crown Point. Here it takes a northeasterly course, and crosses to Chimney Point, at the southwest part of Addison, Vt. An anticlinal commences here, with the Trenton overlying it upon both sides. It was in this northeasterly direction through the whole of the west part of Addison County. The anticlinal has been observed at both ends, but has not been traced through the intervening space, because of the great difficulty experienced in discovering any of the older rocks; this whole region being completely covered up with Champlain clay. We are almost inclined to believe that the so called calciferous sandrock, at the foot of Snake Mountain, in Addison, is Chazy limestone. This might relieve us of the necessity of supposing a fault to exist west of Snake Mountain; for the anticlinal in Chazy limestone is sufficient to account for the presence of Trenton limestone on the lake shore, and the presence of an older rock at Snake Mountain dipping east.

We will mention the localities at which we have found Chazy limestone between Bridport and Charlotte, that any who choose may examine our data, and draw inferences from them for themselves, if they are not pleased with ours. *Maclurea magna* is found at Grosvenor's mill upon the west branch of Dead Creek, in Bridport; also south of E. S. Pettibone's house, in the northwest part of the same town. It is found at Chimney Point, at the Ferry and near the house of Gen. J. Strong. At the west foot of Snake Mountain, it is seen at several places, particularly south of Truman Smith's house. In the west part of Panton it appears for two or three miles, and the house of Judge Shepherd is near a fine locality of its characteristic fossil. In Waltham, near F. E. Benton's house, which is opposite to a school house, it is displayed in great beauty. We regard the rock at Vergennes Center as Chazy, although no fossils were discovered in it. The same kind of limestone occurs west and north of Vergennes in several places, but without characteristic fossils. Along the coast of Ferrisburgh the *Maclurea* is generally present, at every exposure of rock. Prof. Adams found the same in the northwest part of Ferrisburgh, away from the shore. Prof. Emmons says that it occurs east of the shore in Charlotte, with a westerly dip. These are the principal localities of this rock in Addison County.

At Charlotte the shore south of Mc Neil's Point is mostly composed of bluffs of the Chazy limestone. At this point it passes under the waters of Lake Champlain, to re-appear upon the New York side, in Valcour Island and upon South Hero, in Vermont. Providence Island, Straw Island and a lone rock near Carlton's Prize, are mostly composed of Chazy limestone. It enters South Hero at the west side of Martin's bay, embraces the rocks about Merriam's Bay, McBride's Bay, Sawyer's Bay, Sawyer's Island, and

* Vide Geological Report, 2d District, New York, p. 278, and Plate VI, Fig. 1.

perhaps the two Sister's Islands. It is only the west border of South Hero that is composed of this rock, but it is well developed, and its fossils are numerous, as at Merriam's Bay. West of Lake Champlain, in New York, this rock is found two miles below the village of Westport, the village of Essex, at Chazy, at Point au Roche, and from thence north to the Canada line. In Vermont its most northern exposure is upon Isle La Motte.

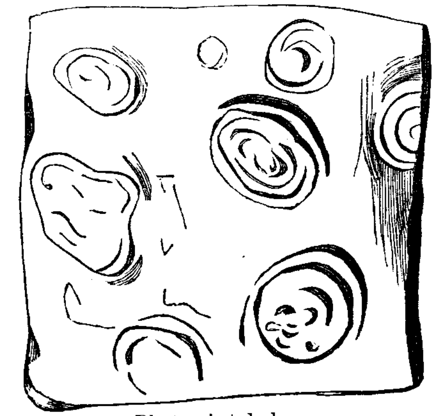
Upon Plate VIII, Fig. 3, the dark blue color denotes the extent of surface covered by this rock, in Isle La Motte. It occupies the whole of the south part of the Island, while Trenton limestone occupies the north east part. The northwest part is entirely covered with Champlain clays and sand; even to such an extent that the rocks are not reached in digging wells. This plate shows all the objects of interest upon this island that have been so often referred to above. This plate was reduced from one executed by Prof. Thompson, for the Geological Report—ten years ago.

The Chazy limestone covers more surface in Vermont than any other of the lower silurian limestones, and it seems to be one of the thickest. We have no sections from which to deduce its thickness, except the Snake Mountain section, and one at Larrabee's Point; both of which represent this rock where it is comparatively thin. We should estimate it to be nearly 300 feet thick, where it is most abundantly developed.

FOSSILS IN CHAZY LIMESTONE.

The following species of fossils have been obtained from the Chazy limestone of Vermont. They are *Phytopsis tubulosum* (Hall), *Rhynchonella altilis* (Hall), *R. plena* (Hall), *Maclurea magna* (Hall), *Cyrtoceras*, ——, *Bucania*, ——

FIG. 175.



Phytopsis tubulosum.

The genus *Phytopsis*, a marine plant, is characterized by a great variety in the shapes of the stems; for the stems may be cylindrical or subcylindrical, straight or flexuous, erect or procumbent, and are generally branched. The branches are diverging and anastomosing; their structure is cellular, consisting of thin laminæ with transverse divisions. Other portions present a reticulated structure.

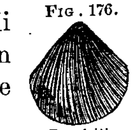
The species *P. tubulosum* has a subcylindrical, sometimes obtusely angular or compressed and branched stem; the branches inosculate obliquely, or in an ascending direction; the external covering of the plant is quite thin; and the center is usually filled with softer materials than the outside, or crystals of some mineral.

Fig. 175 represents a horizontal or transverse section of some of these stems, showing a concretionary arrangement of the calcareous matter around them, which presents the appearance here represented by weathering. Such examples are common in the Chazy limestone in the northwest part of Ferrisburgh.

Rhynchonella altilis (Hall.) *Rhynconella* is a mollusk related to the genus *Spirifer*. The shell is trigonal, acutely beaked, usually plaited; dorsal valve elevated in front, depressed at the sides; ventral valve flattened, or hollowed along the center, hinge plate supporting two slender curved lamellæ; dental plates diverging.

Fig. 176 represents the dorsal valve of the *Rhynchonella altilis*. The description of the shell is the following: "Rotund; valves almost equally convex, rapidly attenuating from the middle to the beaks; beak of the dorsal valve small, acute, incurved over the other, which is closely appressed to the dorsal valve; surface of each valve marked by about twenty-four equal rounded radii; eight of the radii are slightly depressed upon the back of the dorsal valve, and much elevated in front, meeting an equal number of slightly elevated radii of the ventral valve." This species resembles some species of this genus higher up in the series.

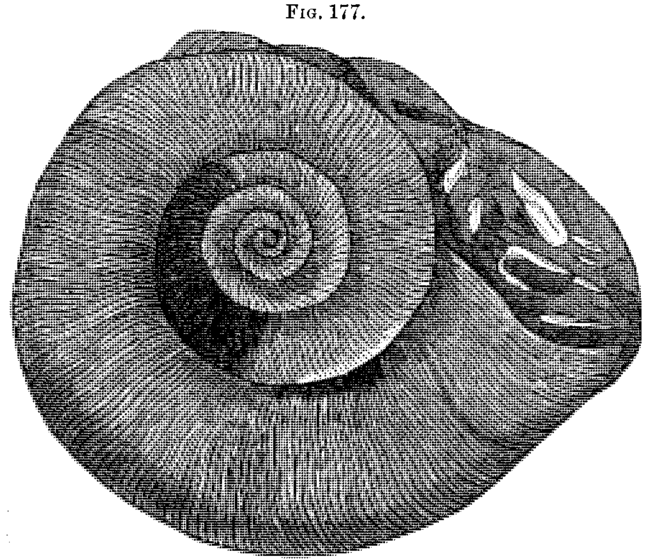
FIG. 176.



R. altilis

This species is abundant in the rocks at Merriam's Bay in South Hero. Some of the strata seem to be entirely composed of the shells. It is very near the top of the Chazy limestone. At the time of our visit there we thought we detected certain fossils of the Trenton limestone in connection with the *Rhynchonella altilis.*

Fig. 177.



Maclurea magna.

Rhynchonella plena (Hall.) Our notes state that *Rhynconella plena* is also found at Merriam's Bay. This shell is "somewhat quadrangularly gibbous or rotund; front margin elevated in a moderately deep sinus; beak of the dorsal valve small, closely incurved over the beak of the ventral valve; surface marked by sixteen to twenty strong radii, about four or five feet of which are depressed, forming the sinus of the dorsal valve, and an equal number elevated above the others on the ventral valve."

Maclurea magna (Hall.) This is a large beautiful univalve gasteropod mollusk, which is the best characterized species of the Chazy limestone.—The description of the genus has already been given under calciferous sandrock. The species *M. magna* is described in the following language: "Sinistrorsal, discoidal, depressed turbinate; breadth more than twice as great as the height; spire flat, a slightly depressed line at the sutures; whorls about six, gradually increasing from the apex, ventricose, flattened above, obtusely angular on the outer edge; surface marked by fine striæ, which, upon close examination, are found to be produced by the imbricating edges of lamellæ; striæ undulating, bending backwards from the sutures, and forwards in passing over the edge of the shell; aperture obtusely trigonal, depressed above, slightly expanded beyond the dimensions of the whorl just behind it; axis hollow; umbilicus broad and deep, extending to the top of the spire."

Fig. 177 represents the upper surface of the *Maclurea magna.* This is only one of many positions in which it may be seen upon the surface of ledges. Sometimes the shell has been distorted by pressure; as is the case in several specimens in the State Cabinet from the northwest part of Ferrisburgh.

Wherever the Chazy limestone occurs in Vermont, we may expect to find the *Maclurea magna.* It is abundant at Larrabee's Point in Shoreham; at Judd's quarry of black marble; in a great many places in Bridport; in Addison, particularly at the base of Snake Mountain; in the west part of Panton, where some of our best specimens were obtained; in Vergennes; on the west side of Bush Mountain, southeast of Vergennes; in the west part of Ferrisburgh; in Charlotte; all along the west part of South Hero; and in the southern portions of Isle La Motte, particularly in the limestone at Hill's south quarry. One of the best places to procure specimens of it for cabinets, is at the mill at Swanton Falls, where this rock is sawn for architectural purposes. There are many buildings in Vermont made of the Chazy limestone, in which this beautiful shell may be seen to advantage.

Because of the wide geographical distribution and the limited geological range of this shell, it is of great value in the identification of strata. Prof. James Hall says that "in the contorted and partially altered limestones of Eastern New York and Vermont, where nearly all other remains are obliterated, I have found the various sections of this shell, often compressed or distorted, but frequently, and almost always sufficiently clear to identify the mass."

Cyrtoceras. In Addison, at the base of Snake Mountain there occurs an undetermined species of *Cyrtoceras,* in connection with *Maclurea magna.* The specimens of it are quite numerous. The characters of the genus are these: Shell curved or partially involute, sometimes with the transverse, at others the longitudinal diameter the greater. Aperture often contracted (in the smooth forms.) Siphuncle subinternal, central or external. This is a chambered shell, partially curved, in distinction from the straight forms of the Orthocerata.

Bucania. An undetermined species of this genus of mollusks was collected in Ferrisburgh. This genus was proposed to include several species of shells of a peculiar form, usually referred to *Bellerophon,* from which they differ in having all the volutions visible. It is a convolute shell; spire equally concave on either side; volutions in the same plane, all visible, outer one ventricose, inner ones usually angulated on the edge, concave on the ventral side; aperture rounded-oval, somewhat compressed on the inner side by contact with the next volution, laterally and dorsally abruptly expanded.

In the first volume of the Palæontology of New York, Prof. Hall describes a species of coral from Vermont, near Granville, N. Y., under the name of *Stictopora glomerata.* A specimen is figured in that volume, Plate IV, Fig. 5. It consists of a surface several inches square, covered and crowded with this coral, completely denuded of its celluliferous crust. Its appearance is very similar to certain specimens of *S. fenestrata* (Hall), though its mode of growth is considerably different. It was principally from this circumstance, and the impossibility of defining the external characters of the coral, that it was referred with some hesitation to a distinct species. The specimen came from a limestone containing *Maclurea magna,* which establishes satisfactorily its position in the Chazy limestone.

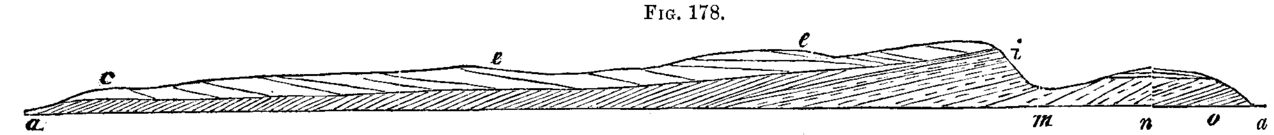
Upon Isle La Motte there are many layers of limestone, mostly made up of fragments of crinoidal columns; but no portions of the other parts of the animals.

Among these crinoidal columns there are small rolled masses, in the shape of acorns or eggs, which are referable to the genus *Chætetes.*

Geological Position and Equivalency.

This rock is intermediate between the Trenton limestone and the calciferous sandrock of the New York Survey. We give a section taken from Prof. Adams' Second Geological Report, with his description, to illustrate its position:*

Fig. 178.



Section across Larrabee's Point, Shoreham.

"The accompanying figure (Fig. 178) represents a section across Larrabee's Point in Shoreham, with a direction from north to south, one hundred and fifty rods long, and fifty feet high. The strata dip 10° north. *a,a,* level of Lake Champlain; *c,* bluff of brown clay, overlying Trenton limestone, which has been worn down to an even surface, and scratched by drift agency; *c, c,* brown clay; *i,* conformable junction in Judd's quarry of the Trenton limestone and Isle La Motte [Chazy] limestones, indicated by change of fossils; *Favosites lycoperdon* being common in the upper strata, and *Maclurea magna* occurring less frequently in *m,* the lower beds. The upper are rather thin, but the lower beds are very thick and compact, furnishing the black marble; *n,* thick-bedded limestone jointed; *o,* thin slaty layers, with slender fucoids abundant." The beds *o,* belong to the calciferous sandrock; and thus the Chazy limestone is shown in its usual position.

We have noticed no mineral in this formation, except pyrites. Prof. Adams' notes mention the existence of this mineral in large quantities at Carlton's Prize, a small island at the southwest corner of South Hero. Upon this island there is also some bog iron ore of inferior quality, that has probably been derived from the decomposition of the pyrites. Under "UnstratifiedRocks," several dikes that occur in this formation will be described with their constituent minerals.

BIRDSEYE LIMESTONE.

The next rock in the lower silurian series in New York, and elsewhere, is a peculiar limestone of thirty feet thickness. It is generally a bluish or light dove-colored limestone,

* See page 164.

so homogeneous that it resembles flint—brittle, breaking with a conchoidal fracture, and the surface of it often presents numerous crystalline points, whence its name.

The birdseye limestone is very rarely found in Vermont. Prof. Adams collected specimens of it with its characteristic fossils, and the present corps of surveyers found specimens of it at South Hero, Ferrisburgh, and at Crown point. We did not discover it at Isle La Motte, although the distinctions are so clearly drawn there between all the other limestones of the lower silurian.

The characteristic fossil is the *Phytopsis tubulosum* (Hall), which we have already described is one of its obscurer forms. The crystalline points which give the name to the rock, are produced in the interior of this fucoid; and they sometimes remain even after every other trace of the vegetable has disappeared. Besides the *Phytopsis tubulosum*, we have obtained but two species of fossils in this rock in Vermont, and these are too indefinite to allow the determination of anything but their generic character. They belong to the genera *Maclurea* and *Orthoceras*, and are from the northwest corner of Benson. The *Phytopsis cellulosum* (Hall), has also been found in Vermont. "Its stems are subcylindrical or compressed, diverging from a center or root, procumbent or ascending, branching; its branches are irregularly anastomosing, forming a close strong net work; the crust or covering is thin; its substance cellular; cells oblong, quadrangular or stellate." The *Phytopsis tubulosum* and *P. cellulosum*, when crystallized in a compact rock, cannot be distinguished from each other. In perfect specimens, they may be distinguished by their internal structure and mode of growth. The former species is the more common one in the Mohawk Valley of New York, and the latter species is the more common one in the northern part of the Champlain Valley.

There are two species of trilobites in the birdseye limestone on Isle La Motte, *Calymene multicosta* (Hall), and *Illænus crassicauda* (Dalm.) The genuine relations of the first species are not fully determined. The thorax and caudal shield have, at least, twenty-five articulations. This species has been discovered only at Isle La Motte, and though obscure, was determined to be evidently distinct from anything else in the older strata of New York. Prof. Hall figured it in the hope of calling attention to the occurrence of such a species, particularly to the explorers of Vermont Geology.

Illænus. Head semi-elliptical or globose, usually wider than long, or transverse; eyes distant and lateral; rings of the thorax simple, eight or ten; pygidium very convex, and trilobation rudimentary.

Illænus crassicauda (Dalm.) The following is the description of the species *I. crassicauda.* "Oval with the longer axis more or less extended, convex; buckler large, convex, rotund; posterior extremities obscure; eyes prominent, distant from the axis; maxillary shield small; thorax distinctly three-lobed, the divisions continuing a short distance into both the cephalic and caudal shields; articulations ten, smooth, slender, those of the lateral lobes extended; caudal shield large, semi-circular, convex, having the rudiment of a central lobe; entire surface smooth, or with fine curving subimbricating lamellose striæ."

The locality of this species is the same with the preceding.

BLACK RIVER LIMESTONE, OR ISLE LA MOTTE MARBLE.

The New York Geological Reports have described one of the best developments of this rock in Vermont, so that we do not deem it necessary to dwell upon it here. It is the black marble of Isle La Motte, which is better developed in Vermont than New York. It is at this locality a black, compact, finely granular marble, and is a pure carbonate of lime. It forms at Hill's north quarry but one bed, from twelve to fourteen feet in thickness. Several well defined vertical joints cut through the marble, and thus the marble can be easily obtained of almost any desired dimensions. When a part of the bed has been removed, the joints make an almost insurmountable wall of the remainder.

The same variety of rocks is also found in the northwest part of Ferrisburgh, where it has been quarried; at Larrabee's Point in Shoreham, where it is twenty feet thick; and in the northwest part of Benson, upon the land of Mr. Orrin Benson. A careful examination of the region would perhaps bring to light the existence of this valuable rock through the towns of Panton, Addison and Bridport.

The characteristic fossils of the Black River limestone occur also in a grayish blue limestone, not very different from the common Chazy limestone.

The *Columnaria alveolata* (Gold) has been found at a locality a few rods east of Highgate mineral spring; at Hill's north quarry of black marble on Isle La Motte; upon an island in Button Bay in Ferrisburgh; and at McNeil's Point in Charlotte. Upon the island in Button Bay is a very profuse display of fossils, particularly of coralline forms.

Upon Plate VIII, Fig. 3, will be found a geological map of Isle La Motte, in which the amount of surface of the Black River limestone is represented. When the apparently smooth faces of the joints in the black marble at Hill's north quarry are examined with a microscope, they will be seen to be studded over with projecting points, a section of which presents a very rough appearance. Many of these projections are composed of crystals of sulphate of strontian.

The fossils of the Black River limestone are more numerous, in proportion to its thickness, than those of any preceding group of lower silurian strata. Some interesting results have been derived by the comparison of catalogues of species obtained from it in Canada, New York, and Tennessee; to which we should have been glad to contribute, had our opportunities for the examination of the Vermont strata been sufficiently extensive. The following species have been found in this rock in Vermont, which will, for convenience, be described under Trenton Limestone: *Columnaria alveolata* (Gold.) *Stromatocerium rugosum* (Hall), an undetermined species of *Chætetes*, *Streptoplasma profunda* (Hall), *S. corniculum* (Hall), *Tetradium columnare* (Hall), crinoidal columns, an undetermined species of *Phytopsis*, *Orthoceras annellum* (Con.) *O. vertebrale* (Hall), and *Orthis pectinella*, (Con.) All these species except *Streptoplasma profunda*, and the two species of chambered shells, are from the island in Button Bay, in Ferrisburgh.

TRENTON LIMESTONE.

We use this term to include the Trenton limestone of the New York Reports.

Lithological characters.

One very soon learns to distinguish this rock in Vermont, from all others, by its common characters of black schistose layers, associated with slaty seams of limestone and occasionally argillaceous matter. There are other varieties, however, that can be assigned to this formation only by their fossils. Certain layers, for example, in Benson, cannot be distinguished lithologically from the coarse thick-bedded limestones of the calciferous sandrock. The following are the chief varieties:

1. Shaly black limestone, scarcely differing from Utica slate.
2. Black compact schistose limestone, the layers of which are separated from one another.
3. Slaty layers, sometimes argillaceous.
4. Gray thick-bedded strata.

5. Light blue compact schistose limestone.
6. Ordinary limestones metamorphosed into white, grayish white, and dirty looking ferruginous strata, frequently with a network of veins of calcite or quartz.
7. Bituminous and fetid layers.
8. Sandy limestones.

Perhaps other unimportant varieties might be added to the list, were it desirable. The most common of all are the second and third, interstratified with each other; and they may be seen at almost any exposure of this rock, between West Haven and Charlotte. Where the rock passes into Utica slate, the first variety abounds, uniformly perhaps,—at all events we cannot distinguish the upper part of the Trenton from the Utica slate except by its characteristic fossils. The black limestone is quite compact in structure, and is quite pure carbonate of lime, breaking with a conchoidal fracture. It contains fossils, sometimes quite scantily; but in this case the fossils are well formed and very beautiful.

None of these varieties are suitable at all for building stone, except the fourth variety, and that is not very common. There was more of it seen upon the west side of South Hero than elsewhere, where it abounds in very fine fossils. In Canada, this variety is used extensively for building purposes.

The fifth variety is found in those regions bordering upon a metamorphic rock, as at Highgate Springs, where it greatly resembles some varieties of the sparry limestone of other groups.

Metamorphism has changed these limestones into white limestones of great purity, at Highgate Springs, where it is burned for lime. Near these beds the limestone is hard, thick-bedded, and compact, much like some varieties of Chazy limestone. Even layers of crystalline mica schist may be seen among them. In the south part of the terrain, in Benson and Orwell, the limestone is utterly unrecognizable, and hard specimens might pass for the metamorphic Eolian limestones. Some of the beds, also, could not be distinguished from some varieties of the red sandrock series in Highgate, etc. So true is it that metamorphosis totally alters rocks, and we are obliged to name rocks by conjecture if we judge by lithological character alone. Most of the unaltered varieties are more or less fetid, and many are so bituminous as to blacken the hands, or any white substance, rubbed upon it.

The sandy limestones were seen only at Highgate Springs, and that in limited amount. They correspond in structure with varieties of both the lower groups. The lithological characters of the Trenton limestones, like its fossils, are better marked than those of any other group in the whole silurian system.

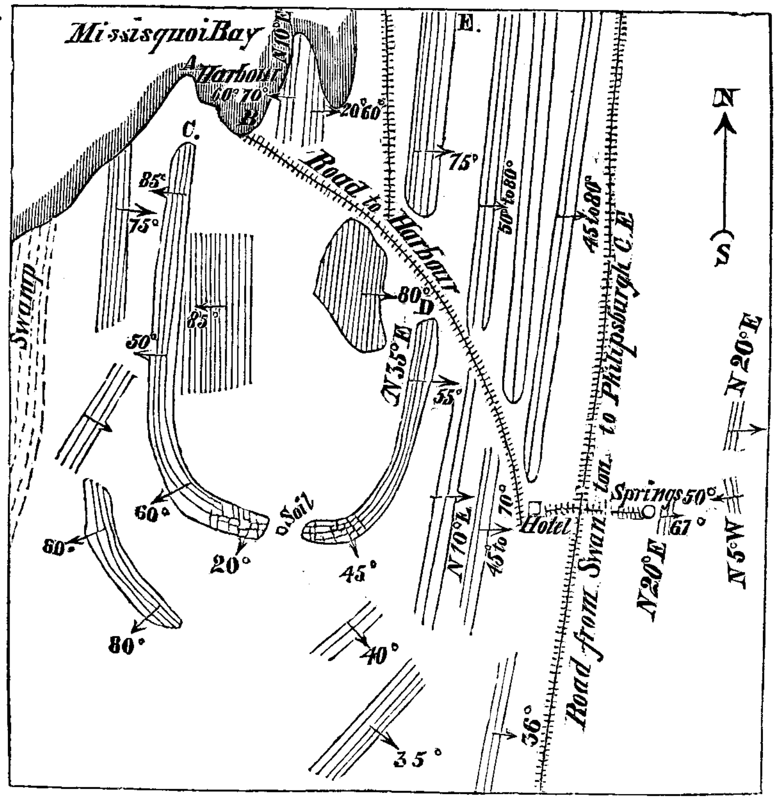
Divisional Planes. Cleavage planes are common in this limestone. They are not generally perpendicular to the strata seams, but cross them transversely at various angles. As this subject has received little attention in the progress of the survey, it is only occasional observations that can be presented. Only two measurements were taken. One at McNeil's Point in Charlotte, gave the strike as N. 20°E. and the inclination 70°E. Another at Porter's Landing in Grand Isle, gave for the strike N. 70°E. and for the dip 38°S. These measurements represent their average position throughout the whole formation in Vermont.

Jointed seams are common. They usually cross the strike at right angles, and are perpendicular, at intervals varying from two or three inches to ten feet.

STRIKE AND DIP OF THE STRATA.

Locality.	*Strike.*	*Dip.*	*Observer.*
West Haven,	About N. and S.,	5° E.,	C. H. H.
Orwell, south part,	About N. and S.,	3° E.,	C. H. H.
Larrabee's Point,	N. 60° E.,	12° N.,	C. B. A., C. H. H. and A. D. H.
Shoreham, northwest part,	N. 20° E.,	20° E.,	C. H. H.
Bridport, Frost's Landing,	N. 40° E.,	10° N.W.,	C. H. H. and A. D. H.
Bridport, Frost's Landing,	N. 40° E.,	5° S.E.,	C. H. H. and A. D. H.
Addison, north of Chimney Point,		15° W.,	C. H. H.
Bridport Village,	N.E. and S.W.,	S. E.,	C. H. H.
Addison, Snake Mountain,	East of north,	25° E.,	C. B. A. and C. H. H.
Waltham, north part,	Generally small to east.	Once even. 75° N.	C. H. H.
Ferrisburgh, east of Vergennes,		Dip east,	C. H. H.
Charlotte, McNeil's Point,	N. 20° E.,	15° E.,	C. H. H. and A. D. H.
Charlotte, do., north side,	N. and S.	9° E.,	C. H. H.
South Hero, south part,		Horizontal,	C. H. H.
South Hero, south part,		4° W.,	C. H. H.
Providence Island,		About 20° N.,	C. B. A.
Carlton's Prize,		Much contorted,	C. B. A.
Grand Isle, Porter's Landing,	N. 70° E.,	2° S.E.,	C. H. H.
Grand Isle, near Tobias Landing,		6° northerly,	C. H. H.
Grand Isle, south of Porter's,		12° N.,	C. B. A.
Isle La Motte, north part,		5°–6° N.E.,	C. H. H.
Highgate, south of springs,		Dip east,	C. H. H.
Highgate Springs, north of hotel,	N. 10° E.,	45° E.,	C. H. H.
Highgate Springs, do.,	N. 42° E.,	32° E.,	C. H. H.
Highgate Springs, south of hotel,	N. 28° E.,	36° E.,	C. H. H.

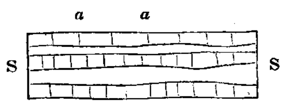
Fig. 179.



Dip and Strike of Trenton Limestone at Highgate Springs.

The variation in the dip and strike at Highgate Springs and vicinity is so great, and so many observations were recorded, that we give a sketch of these irregularities from the note book of the Principal of the Survey. The figure includes a space 200 by 175 rods, and though the strikes have not all been laid down with strict accuracy, their general position is correct. One of the most remarkable things to be noticed is the great curve in the strata, from C to E, and the accompanying anticlinal from A to C, the distance is 20 rods; from C to the break in the strata, 93 rods. The width of this gap is 11 rods. The length of the remainder to D, is 55 rods. Thus the length of the curve from C to D is 159 rods; and from C to E, the distance is over 200 rods. Where the bend is greatest, the strata are much broken, and the fractures are mostly filled with veins of calcite. Fig. 180 shows these veins of calcite crossing alternate strata of limestone, upon the west side of the curve. The short lines *a*, *a*, represent the veins in the strata, S, S.

Fig. 180.

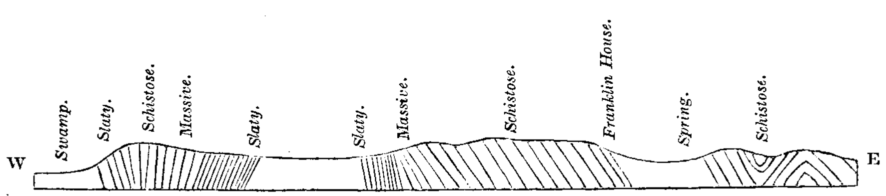


Segregated veins, Highgate.

Inside of the curve there are a few ledges; all of which are represented upon this sketch. At the point of land jutting out into the Missisquoi Bay, the strata are beautifully plicated. South of the road to the Harbor there are two ledges dipping in opposits directions, which are largely composed of a slaty rock, containing only a small per cent. of lime. Another curve can be traced around the inner one; but the dip varies upon the west side from the inclination of the inner one. The dip of the ridge upon the east does not vary much from that of the inner curve; but if it be followed round, it will be noticed that the dip of the outer curve at the southwest corner of the figure is twenty degrees greater than that of the inner one—in fact it is almost perpendicular. The same ledges, continued, dip at a very high angle to the east. We suppose that the normal dip of this ridge is to the west, but the lateral pressure from the east, which folded the strata, was so strong that it pushed the whole fold to the west, and thereby brought the west part of the west side of the anticlinal under the east part of the same. And as a force always acts with the greatest intensity at right angles to its direction, therefore the strata upon the south side of the curve have more of the normal dip than those upon the west side.

The rudiments of a third and fourth curve appear upon the figure. It would be difficult to trace them out as fully as the inner ones, because the ledges are mostly covered up south of what is represented in the figure. The next southern ledge of Trenton limestone that we have seen, is at Mr. O'Neil's house, less than two miles south of the Franklin House. These curves seem to indicate the southern extremity of the Trenton limestone. This range increases in width as it passes into Canada, being the widest at Philipsburgh, at the head of Missisquoi Bay. It extends to Deschaillons upon the St. Lawrence, below Montreal. It lies between ranges of the Hudson River Group, according to the Canada survey, and is the basis of the great anticlinal dividing the Palæozoic rocks of Canada into two basins, the eastern and the western, as denominated by Sir W. E. Logan; the one extending to the western United States, and the other to the Atlantic Ocean.

Fig. 181.

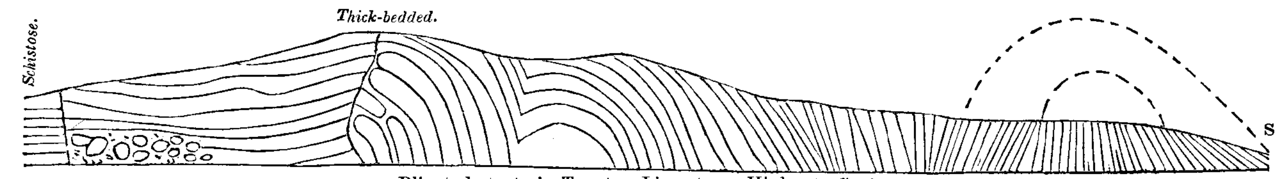


Section in Trenton Limestone at Highgate Springs.

Fig. 181 represents a section crossing the ridges delineated in Fig. 179. The character of the limestone is given to the principal varieties in the sketch. West of the ledges there is a vast swamp, extending over the east part of Hog Island. It is upon this swamp that we should expect to find the calcareous slates above the Trenton; but their easily decomposed nature has worn them away, as it has done upon the east side also.

The character of some of these folds is shown in Fig. 182. It is taken at B in Fig. 179, between the shore of a small bay or harbor and the end of the point, and is about twenty-five rods long. There are at least three folds, the most southern of which has its arch worn away. The most northern fold has a crack running through it. Most of the layers are quite thick—from four inches to a foot. A pile of bowlders and debris near the north end, obscures some of the lower strata. The whole section may be seen to the best advantage by sailing near the shore.

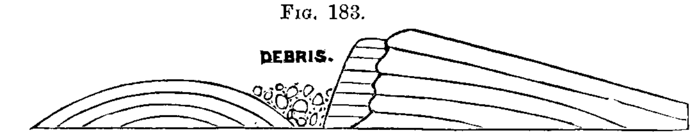
Fig. 182.



Plicated strata in Trenton Limestone, Highgate Springs.

The rock seems to have undergone a partial metamorphosis, in that it is unusually compact, is of a grayish color, and some portions of it ring when struck by a hammer. A little east of the sketch the rock becomes whiter; and Fig. 183 represents the position of the strata there. It is upon the east side of the same point.

Fig. 183.

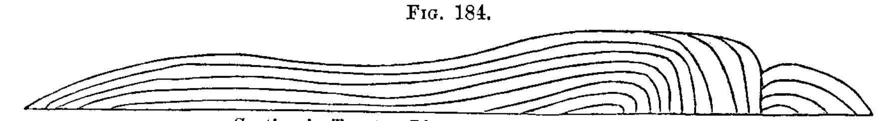


Section in Trenton Limestone at the Point.

Upon the next point of land, which is not represented upon any of the cuts, the limestone is white, and is very pure carbonate of lime. Its color seems to be due to its metamorphosis, as may be also its purity. It makes an excellent quick lime, large quantities of which are annually manufactured and sent to market.

Fig. 184 shows the position of another metamorphic mass of limestone, upon a small island north of the harbor. There are two curves upon it, and one of them has the steep slope, so common to one of the sides of a fold.

Fig. 184.

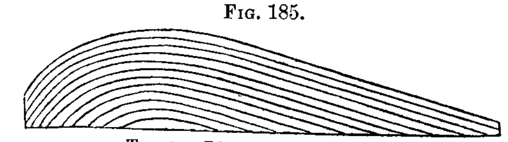


Section in Trenton Limestone upon the Island.

Highgate Springs is a fine place to study Geology. A large number of fossils are found there in the Trenton limestone, and two miles east is the only locality of animal remains in Vermont that occur in the red sandstone series. Both these formations present a great many curves in their strata, which are finely exposed for examination. Not less interesting are the deposits of limestone of the Hudson River Group, and the Champlain clays. The naturalist will find it an excellent place to procure the fishes of Lake Champlain; and if he is a little indisposed, the excellent sulphur spring water, with the good care and attention of Mr. Averill, the intelligent proprietor of the Franklin House, whose hospitality we have renewedly enjoyed, will quickly restore him to health.

Most of the Trenton limestone in Vermont, dips to the east at a small angle. The exception is found in those patches that lie west of the Chazy limestone, upon Lake Champlain. In the northwest part of Panton it has a variable dip; sometimes it forms a graceful curve like Fig. 185. This is about thirty feet high, and several rods long.

Fig. 185.



Trenton Limestone in Panton.

Utica slate is associated with much of the Trenton limestone between Panton and Chimney Point, and many sketches might be given, as in Fig. 216, where the Trenton limestone forms another arch upon a larger scale, and passes under the overlying slate.

Range, Extent and Thickness.

There are three ranges of Trenton limestone in Vermont. The principal one enters the State in West Haven, passes through Rutland and Addison Counties into Charlotte, through the towns of Benson, Orwell, Shoreham, Bridport, Addison, Waltham, and Ferrisburgh. It then loses itself in Lake Champlain, re-appearing upon Grand Isle, South Hero, and Isle La Motte. The second range is found upon the west flank of the anticlinal in the Chazy limestone upon the lake shore, in Bridport, Addison, and Panton. The third range is found in Vermont only in Highgate.

Concerning the principal range we will speak first. A little less than a mile west of West Haven Post Office, it appears as a light blue limestone, capping several small hills with a very small easterly dip. It extends west to Codman's Creek. There is but little thickness to it, while the calciferous sandrock beneath is enormously developed, as if nature had exhausted herself by producing the latter, and during the Trenton and Chazy periods was gradually recovering herself. In Benson, west of the village, this rock is developed in an exceedingly inferior style. Rapacious metamorphic action has clutched it, and left hardly any one of its peculiar characteristic forms and colors, by which it might be recognized. The rock is gray, thick-bedded, with veins of calcite passing through it, and it has a sort of neglected appearance. The same description applies to this rock as it appears through most of Benson and Orwell. Occasionally a few obscure fossils appear, which are the chief guide to the age of the rock,—as for example, west of Z. Nearing's house in the southwest corner of Orwell.

The next observed exposure of this rock is near O. H. Bascom's house, in the west part of Orwell, upon Section VII. We found no fossils, but relied mainly upon its position for its place. Its lithological character is obscured by metamorphic action. We suppose this to be the rock that Prof. Emmons in his work on American Geology, calls Trenton limestone.

At Larrabee's Point, in Shoreham, all doubt as to the age of this belt is put at an end, by the fine development there of all its characteristic fossils. The rock is confined mostly to the point, the back land being composed principally of Utica slate. A section is given, in Fig. 178, of the relative position of the Chazy and Trenton limestones on this point. This rock commences at Judd's quarry, and continues to some distance north, even beyond the point. A large surface that has been striated by the drift agency, is finely shown upon the shore, north of the United States Hotel. The fossils may be found at any exposure of the limestone upon the shore of the lake. Some of them, as *Chætetes lycoperdon*, have been washed out from their bed-rock, and are scattered about like pebbles. Other specimens are from the walls of an old limekiln. The heat has calcined the shells without injuring them, and thus they are rendered more distinct. Ripple marks were also observed upon the Trenton at this locality. It is a finer locality for fossils than Highgate Springs.

Passing north we see but little of the Trenton, for, like the Chazy limestone, and other rocks beneath, it sweeps westwardly across the lake to New York. A pinch of it, as it were, is occasionally seen, as near Mr. C. Humsdon's house, near the lake shore, in the northwesterly part of Shoreham. The principal range passes northeasterly from this point into Bridport, east of the Chazy anticlinal. Near Bridport Center (both north and south) the characteristic schists of this rock appears, as they also do in the east part of the town, with the characteristic Chætetes. The latter locality was shown us by Rev. Augustus Wing. Next it appears at several places in Addison, west of Snake Mountain, with its fossils. It next sweeps eastwardly around the northwest corner of Snake Mountain into Waltham. In the north part of Waltham it appears with it fossils and undulatory dip near S. Burrough's house. East of Vergennes it is also seen; as in Ferrisburgh, at two or three places on the principal road between Vergennes and Burlington. It is now trending towards the lake, which it reaches at McNeil's Point in Charlotte. One or two of the islands south of the point are composed of this limestone as well as Great Bluff Point. There are many good fossils at McNeil's Point, for many of which we are under obligations to Mr. McNeil. We learned by experience that some of his neighbors prized these relics as well as himself. One of our surveying parties came up the lake in a skiff, and landing north of the dock, commenced to examine the rocks. A beautiful coral arrested their attention, and mindful of the interests of the State Cabinet, began to pick about it with appropriate tools. It yielded to their labors; but just as they were extracting it from its firm socket, a gruff voice arrested us. "Here, let that are thing alone, its one of the most curest things on my farm, and I ain't a goin' to have it carried off!" Of course they relented, and apologized for having trespassed—though unwittingly—for they knew of no statute forbidding members of the Geological Survey to collect specimens of rocks or fossils, within the precincts of the State. They departed, leaving the coral, which can probably be seen by visitors to this day, only provided that the water has not washed it away, for it was loosened so much that a slight force would easily tear it up. They were glad, nevertheless, to find that there was some one that appreciated the value of fossils so much, as to be unwilling to part with them, even for a consideration.

This range next appears upon Stave Island and Carlton's Prize, from whence it passes under water to Martin's Bay in South Hero. It occupies the middle and northwest parts of the island. It reaches entirely across the island at one place, to Keeler's Bay, but the shape of the island is such that it runs off to the northwest part, when it again sinks beneath the lake to rise again in Isle La Motte. In Grand Isle is the best development of the Trenton that we have seen in Vermont. Prof. Adams in his manuscript notes thinks the thickness of it here is as much as 500 feet. The strata are thick-bedded, upon the shore north of Rockwell's Bay to near Tobias Landing, and are filled with beautifully developed trilobites, orthocerata, shells, fucoids, etc.

The finest fossils in the Cabinet are from this coast. The best localities on this island are north of Rockwell's Bay, and at Porter's Landing. In fact almost every stratum contains beautiful fossils.

The extent of surface in Isle La Motte covered by Trenton limestone is represented upon Plate VIII, Fig. 3. It occupies the northeast part of the island, and abounds in fossils. It commences at Hill's black marble quarry, and may be seen at the prominent points north, as at Cooper's Point, and at Cemetery Point. A short distance above the black marble, there is a small amount of Utica slate connected with it. According to Prof. Thompson, the Trenton caps the highest parts of this island as well as the northeastern part. We have been able only to explore the shores.

Going back to Bridport we find on the west side of the Chazy limestone anticlinal, an outcrop of Trenton limestone, at Frost's Landing. It forms an anticlinal by itself; for both north and south of it Utica slate is found dipping from it both to the north and to the south. This was found to be a good locality for fossils—especially the Lingulæ. The Trenton occurs next north of Chimney Point, on the west side of the Chazy, which it follows into the State from Crown Point, N. Y. The rock is in place upon the shore a mile north of the ferry, and upon the land at Mr. Strong's house, and at a Mr. Goodale's, according to Prof. Adams. This range gradually thins out in Addison. Prof. Thompson describes Trenton further north in the northwest part of Panton. It is found next, upon the shore, in the southwest part of Charlotte, which is upon the principal range as before described. Perhaps this rock may be continuous under the lake from Panton to Charlotte.

No other range of Trenton limestone has been noticed in Vermont, except at Highgate. This is first recognized as such, a little more than a mile south of the springs, which seems to be its southern limit. Some have supposed that the white limestone in Swanton, at Rich's quarry and near Highgate Falls, are Trenton limestone, in a metamorphic state. That range, however, lies east of, and apparently above most of the Hudson River slate, and overlies the Trenton in Highgate, unless there is a fault between them. There is a small thickness of slate east of Rich's quarry, which is not found east of the dove-colored limestones south of Swanton. It is certain that some of the Trenton is found south of Swanton, even if any are disposed to regard a part of the Swanton limestone as altered Trenton limestone.

This range widens in passing through Missisco Bay to Philipsbury, C. E., and continues north of the St. Lawrence, crossing at Dischaillons, east of Montreal.

The thickness of the Trenton limestone is 400 feet in New York, and is stated by Prof. Adams, in his Second Report, to be of the same thickness in Vermont, but in one of his note books he suggests that it may be even thicker. We should think that 400 feet is rather too great a thickness for it, as it generally appears in Vermont, but have made no measurements to settle the question.

MINERAL CONTENTS.

The principal mineral noticed in this rock, is a large vein or dike of milk-white calcite ten feet wide, at Rockwell's Bay in South Hero. It dips 50° W., while the strata dip slightly to the north. Very good specimens can be obtained from this vein.

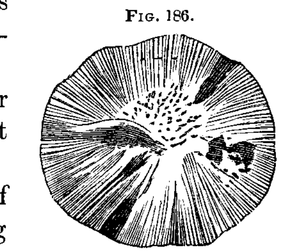
ORGANIC REMAINS OF THE BLACK RIVER AND TRENTON LIMESTONES.

The organic remains of the Trenton limestone as found in Vermont, are the following: A few undeterminal species of marine plants; of corals, *Chætetes lycoperdon* (Hall), and two undetermined species of *Chætetes*, *Escharopora recta* (Hall), *Stictopora ramosa* (Hall), *Stromatocerium rugosum* (Hall), and *Graptolithus amplexicaule* (Hall); one crinoid, *Schizocrinus nodosus* (Hall); of brachiopod mollusks, *Lingula quadrata* (Eichw), *L. elongata* (Hall), *L. obtusa* (Hall), *L. crassa* (Hall), *Crania* (?) *filosa* (Hall), *Discina lamellosa* (Hall), *Trematis terminalis* (Con.), *Strophomena alternata* (Con.), *S. textilis*, *Leptæna sericea* (Sowerby), *Orthis testudinaria* (Dalm.), *O. biforatus*, *var lynx* (Eichw.), and an undetermined species of Delthyris; of acephalous mollusks, *Tellinomya levata* (Hall), *T. nasuta* (Hall), an undetermined species of *Modiolopsis*, and *Ambonychia undata* (Con); of Gasteropod mollusks, *Maclurea Logani* (Salter), an undetermined species of euomphaloid shell and *Bellerophen bilobatus* (Sowerby); of cephalopod mollusks, *Trocholites ammonius* (Con), *Orthoceras amplicameratum* (Hall), *O. strigatum* (Hall), *O. multicameratum* (Con), and *Endoceras proteiforme* (Hall), and of trilobites, *Asaphus canalis* (Con), *Calymene senaria* (Con), *Ceraurus pleurexanthemus* (Green), and *Trinucleus concentricus* (Hall).

FOSSIL CORALS.

Chætetes lycoperdon. This is a very common species of the Trenton limestone. It often occupies certain layers to the entire exclusion of other fossils; and its branches often cover many yards of surface. The coral is polymorphous, composed of closely aggregated tubes or columns, which diverge gradually from a broad base forming hemispherical masses, or from an imaginary axis producing conicular ramose forms; tubes minute, fibre-like, traversed by diaphragms; no connecting pores; the coral increases by sub-divisions of the parent tube, or by the successive addition of lateral or marginal tubes; exterior envelope sub-membranous.

Fig. 186.



This coral appears in various forms; either hemispherical, conical, nearly globular or ramose. The most common form is the hemispherical, greatly resembling that fungus which is commonly called a puff ball. Fig. 186 represents this form.

This species ranges from the bottom of the Chazy limestone through the whole of the silurian system, and is perhaps introduced again in the Hamilton and Chemung groups. We have found it in Vermont in Shoreham, at Larrabee's Point, at Frost's Landing and the village in Bridport, at the base of Snake Mountain in Addison, in Waltham, Ferrisburgh, McNeil's Point in Charlotte, at various localities in South Hero and Grand Isle, at the north end of Isle La Motte, and at Highgate Springs.

Tetradium columnaris (Hall.) The genus *Tetradium* resembles some forms of Chætetes. Its coralla are massive, consisting of four-sided tubes, and cells with very thin septa or parietes; cells stellate with four narrow laminæ. This genus differs from *Receptaculites* in having very thin parietes and four distinct rays within the cells, one to each side. The cells are about half a line in breadth. The tubes, in the different species, vary from one-fourth of a line to nearly a line in breadth: they are very long, and are most frequently united throughout laterally, forming massive coralla, somewhat resembling that of Chætetes; sometimes they are united in single intersecting series; not unfrequently too the tubes are isolated, or only united at irregular intervals. The *isolated tubes* are nearly quadrangular, the edges being more or less rounded. There is a slight linear depression down the middle of each side externally, opposite the lamellæ. The increase of the coral appears to be by the division of the tubes, the latter spliting sometimes into two cell-tubes, not unfrequently perhaps into four; opposite lamellæ unite and form the new walls of the young cells, each of which is in the mean time supplied with its four rays.

The following is a description of the species, *T. columnare.* Coralla massive, hemisperical, or flattened hemispherical, composed of diverging tubes. Cell tubes normally four-sided, but often without very much regularity; the walls of the cells rugose; lamellæ very delicate, and generally wanting; breadth of full grown tubes usually about or but little more than half a line. Transverse septa usually absent.

This species belongs to the Black River limestone, and was collected at Button Bay Island in Ferrisburgh.

Columnaria alveolata (Gold). This is the characteristic coral of the Black River limestone, and its localities have already been specified. It is a hemispherical or irregularly massive coral, consisting of radiating, parallel, or diverging tubes; tubes hexagonal (or varying from 5 to 7 sided), striated longitudinally, crossed by transverse dissepiments with vertical radiating lamellæ; no communicating pores.

The vertical lamellæ converge from the sides of the cell towards the center, but probably do not meet at the center. They are unequal in number, varying from twenty to thirty; are often partially obliterated, and leave the inside of the tube marked only by sharp ridges, corresponding to the striæ upon the outside. When the transverse dissepiments are also obliterated, these ridges are denticulated, marking the point of junction. The vertical lamellæ are only visible in the weathered specimens.

Fig. 187.

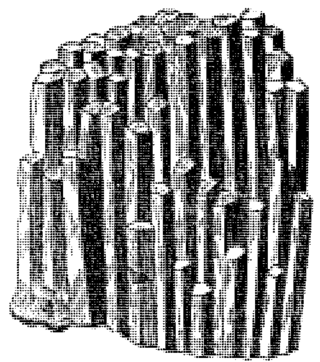


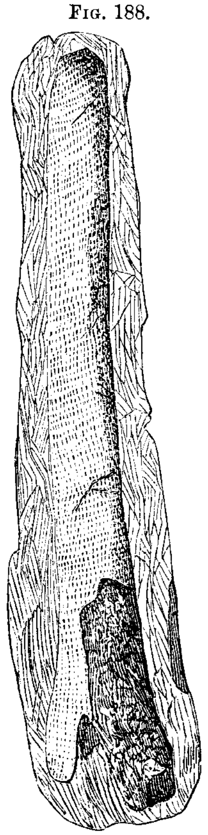
Fig. 187 represents a vertical section of a compact specimen of the *Columnaria alveolata*, showing the striated walls of the cells.

This coral occurs in hemispherical masses, varying in diameter from three inches to three feet, in Vermont. A specimen was discovered in New York which originally must have weighed from 2000 to 3000 pounds.

Escharopora (Hall.) The coral of this genus consists of a solid cylindrical or subcylindrical stem, gradually tapering above, expanded and attached by root-like ramifications below; surface entirely celluliferous; mouths of cellules oval, scarcely contracted, inclosed in a rhomboidal space formed by elevated oblique lines, which cross the coral in two directions; cellules consisting of oval tubes of nearly equal dimensions throughout, which radiate in an ascending direction from an imaginary axis.

Fig. 188 represents a part of *Escharopora recta* (Hall). The coral is straight, rigid, unbranched, cylindrical, or slightly compressed. It is found in Trenton limestone in Vermont, at Larrabee's Point in Shoreham, and in South Hero.

Fig. 188.



Escharopora recta.

Stictopora (Hall.) This is foliaceous, somewhat calcareous, branching coral, attached below by a smooth root-like expansion; stems and branches bifurcating, and sometimes coalescing, celluliferous on both sides, with a thin central axis; cellules consisting of oval tubes, not urceolete or utricular; apertures distinctly oval, with a raised border nearly as large as the cell within.

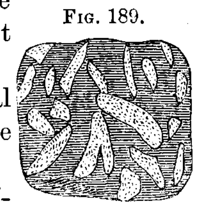
Fig. 189 represents a small piece of rock covered with fragments of the *Stictopora ramosa* (Hall.) It is said to occur in Trenton limestone at Larrabee's Point in Shoreham.

S. ramosa is a branching, erect, somewhat stony coral, covered on both sides by a celluliferous crust; branches flattened; cells oval, in quincunx order; arranged in regular oblique lines, alternating with each other in the direction of the axis, opening obliquely upward and outward; mouths of the cells in perfect specimens elevated; more perfectly rounded at the upper side.

Stromatocerium rugosum (Hall.) This species of coral is exceedingly abundant in the Black River limestone in Vermont. It is found in this limestone upon the island in Button Bay, in Ferrisburgh, and at Isle La Motte. In Trenton limestone it has also been found in South Hero.

This coral is hemispherical; it increases in concentrated laminæ or strata; the laminæ are numerous and wrinkled; and there are some faint indications of vertical tubes or cells. It usually appears as a rough shapeless excrescence upon the weathered surface of the limestone; and a little examination shows it to be composed of concentric layers.

Fig. 189.



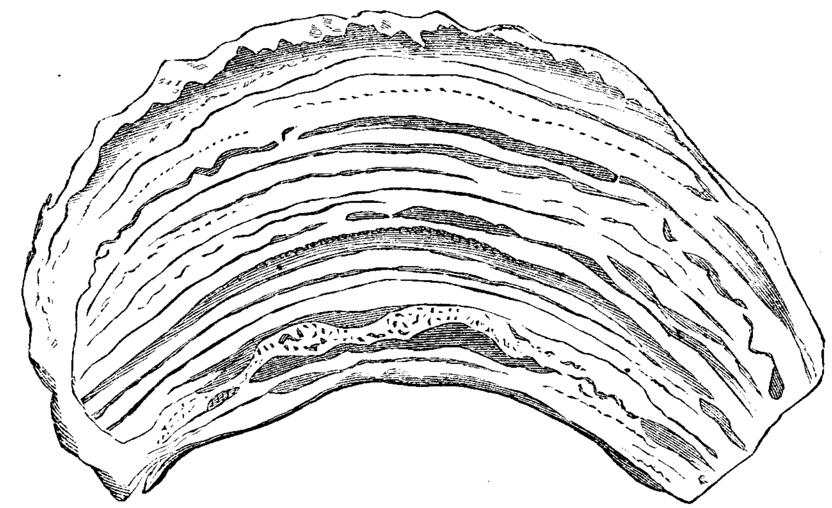
Stictopora ramosa.

Fig. 190 represents a specimen of *Stromatocerium rugosum* of natural size. It exhibits distinctly the concentric lamination of the coral. The coral, however, is often of much larger size than the one figured.

Streptelasma (Hall.) This coral belongs to the family of *cyathophyllidea.* It is turbinate, gradually or abruptly expanding above; form like *cyathophyllum;* terminal cup more or less deep; lamellæ vertical or longitudinal, more or less spirally twisted together when meeting in the center.

S. Profunda (Hall), has been found at Isle La Motte in the Black River limestone. It is obliquely turbinate, often slightly curved near the base, expanding above more or less abruptly; cell profoundly deep,

Fig. 190.

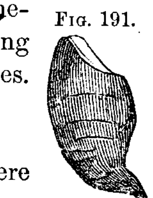


Stromatocerium rugosum.

extending nearly to the base of the coral; margin of the cup reflexed; surface scarcely marked by transverse rugæ; lamillæ from 36 to 80 strong, nearly equal on the margin, but distinctly alternating in length within; no transverse dissepiments or celluliferous structure. This species is figured in first volume of the Palæontology of New York, Plate XII, Figs. 4 to 4*e*.

Streptelasma corniculum (Hall.) This species has been found in the Black River limestone upon the island in Button Bay. It is described in the New York Reports, as occurring only in the Trenton limestone. This coral is turbinate, curved near the base, which terminates in an acute point, somewhat rapidly expanding above; cup profound; lamellæ about sixty; surface marked by strong longitudinal lines indicating the lamellæ, which are crossed by fine concentric wrinkled lines. Its length varies from three-fourths to one and half inches.

Fig. 191.



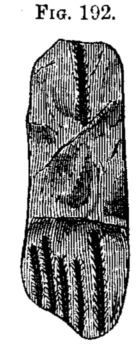
Streptelasma corniculum.

Fig. 191 represents a small and nearly perfect specimen of the *Streptelasma corniculum.*

Graptolithus amplexicaule (Hall). The affinities of the graptolitidæ are treated of elsewhere in this Report. This is the only species of graptolite that occurs in the Trenton limestone. Only fragments of it have been found, which appear to have considerable thickness. The stipes are slender, linear, elongated, surrounded by small sheathing folioles or scales, giving it a serrated appearance; folioles small and acute.

Fig. 192 represents several fragments of the *G. amplexicaule,* in a fragment of limestone. All the stipes except one have been broken off by a fracture of the stone.

Fig. 192.



Graptolithus.

Crinoidea. Numerous fragments of crinoidal stems are found in the Trenton limestone in Vermont, but it has been impossible to identify most of the fragments with any known species. A species of *Schizocrinus* has, however, been found in the Champlain Valley, and therefore we add a description of it. Most of the crinoidal fragments found in this rock in Vermont, belong probably to this genus. The pelvis of the genus *Schirocrinus* is composed of five pentagonal plates; first costals five, joining at their lateral edges; second costals five, separated by a hexagonal intercostal plate, which rests upon the upper lateral edges of the lower costals; scapular and armplates five, hexagonal, the lower side curved and fitting the concave upper edge of the plates below; hand joint double or bipartite, as also the interscapular, or interbrachial plates; hands and fingers regularly bifurcating.

The *Schizocrinus nodatus* (Hall), has its body cup-shaped, obtusely pentagonal, spreading somewhat abruptly from the body; arms short; fingers in ten pairs, fimbriated; column round, composed of joints of unequal thickness and diameter, the larger ones furnished with side arms; surface of the joints deeply striated in radii, which give a serrated appearance to the edges of the plates.

Lingula; shells of brachiopod mollusks. Four species of *Lingula* have been found in the Trenton limestone in Vermont. The shell of the *Lingula* is oblong; compressed; slightly gaping at each end; truncated in front; rather pointed at the umbones; dorsal valve rather shorter, with a thickened hinge margin, and a raised central ridge inside.

Fig. 193 represents a specimen of *Lingula quadrata* (Eichw.), of ordinary size. The shell is equivalve, equilateral, broadly oval, depressed convex; sides nearly straight and parallel, or slightly curved; extremities nearly equal in width, the first broadly rounded, cardinal extremity slightly narrower and somewhat angularly sloped; beak marginal, not prominent; exterior surface of the shell marked by strong concentric striæ, and along the middle by distinct longitudinal striæ, which are equally visible when the outer shell is exfoliated. A longitudinal depressed line marks the shell from the beak nearly half way to the base.

Fig. 193.

Lingula quadrata

This is one of the largest Lingula known. Its usual length is about one inch. Its great size is generally sufficient to distinguish it from all other species of the genus in the Trenton limestone. Other characteristic distinctions are its general elliptical form, its parallel sides, and the longitudinal striæ marking the center of the shell.

Lingula quadrata occurs in Vermont at McNeil's Point, South Hero, and a short distance northwest of the village of Ferrisburgh.

Lingula elongata (Hall). This shell is represented in Fig. 194. It is an oblong, oval shell, gradually narrowing towards the beak, sides nearly straight, shell much elevated along the center, which continues to the beak, and is slightly depressed in front; a narrow, depressed line extends along the length of the shell, from the beak, more than half way to the base; surface marked by fine concentric striæ, without visible longitudinal ones. The shell is $\frac{11}{16}$ of an inch long, and $\frac{6}{16}$ of an inch wide. This is a rare shell, and has been found only at McNeil's Point, in Charlotte.

Fig. 194.

Lingula obtusa (Hall.) Fig. 195 represents a very perfect specimen of this species of large size; but the radiating striæ of the species are scarcely visible. The shell is broad, ovate, obtuse at the apex and regularly rounded below, depressed in front, but very prominently convex on the umbones; beaks obtuse, prominent, not terminal; margin of the shell a little produced beyond the beaks; surface apparently smooth, but, under a magnifier, exhibiting fine concentric and radiating striæ. The shell is easily distinguished by its ovate form, with very obtuse apex; the beak is prominent and elevated, with a narrow space between it and the margin of the shell. The outline from beak to base is much more arched than in any other species.

Fig. 195.

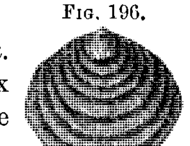
Lingula obtusa.

The *Lingula obtusa* has been collected at McNeil's Point and South Hero.

Lingula crassa (Hall.) This shell is broadly ovate, with a subacute beak; one valve is more convex than the other, and somewhat arched; the shell is thick, marked by strong, concentric, elevated lines, without radiating striæ. The shell is broad and regularly rounded in front, sloping abruptly to the beak. The thick shell and prominent concentric lines are characteristic. The shell is black and less brilliant than the *Lingulæ* usually are. Single valves and fragments of this species are common in Basin Harbor in Ferrisburgh, and just over the State line at Crown Point, N. Y.

Crania. The shell of the genus *Crania* is smooth or radiately striated; the umbo of its dorsal valve is sub-central, marginal, or prominent and cap-like, with an obscure triangular area traversed by a central line.

Fig. 196.



Crania filosa.

Fig. 196 represents the shell of a species of mollusk which is doubtfully referred to *Crania.* It is the *Crania filosa* of Hall. The shell is orbicular; one valve more or less convex; apex marginal; surface radiated with numerous fine, elevated, thread-like striæ, which are more or less prominent, depending on exfoliation of the shell; intermediate striæ coming in between the others as they recede from the beak; but the striæ are not bifurcate. Young shells of this species are very convex, being almost conical; but gradually become depressed and expanded as they increase in age and size.

The specimens of *Crania (?) filosa* collected in Vermont are from South Hero.

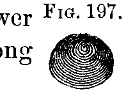
Discina. The shell of *Discina* is orbicular, horny; the upper valve limpet-like, smooth or concentrically lamellose, apex behind the center; the lower valve flat or conical, with a sunk and perforated disk on the posterior side; interior polished; lower valve with a central prominence in front of the foramen.

The shell of the *Discina lamellosa* (Hall), is orbicular, depressed; apex small, but little elevated, situated about one-third the breadth of the shell from the margin; surface marked by elevated lamelliform concentric lines or ridges.

The shell is nearly flat, with the exception of the small apex. The concentric lines appear to be made up of their shelly laminæ.

Fig. 197 represents a ventral view of the *Discina lamellosa.* It is from McNeil's Point, in Charlotte, where so many brachiopod shells are found. It is a rare species.

Fig. 197.



Discina lamellosa

Trematis. In this genus the shell is depressed; valves unequally convex, greatest in the lower valve; umbo of the lower valve sub-central; of the upper marginal; lower furnished with an oblong aperture for the transmission of the peduncle.

The *Trematis terminalis* (Em.) is the only species of this genus in Vermont, and is quite common at Larrabee's Point, in Shoreham, and at McNeil's Point, in Charlotte. The shell is very obtusely subovate or orbicular; ventral valve depressed, convex, with a terminal or marginal apex; dorsal valve very convex or subconical, with a central apex, a broad depression and narrow slit on one side, extending to the margin of the shell opposite the beak of the ventral valve; surface usually smooth, perhaps from exfoliation. Fine longitudinal or radiating striæ are also visible when the shell is exfoliated; these striæ are sometimes punctate.

This fossil is easily recognized by its low, convex suborbicular ventral valve, with a marginal apex. The opposite valve is less often seen, but it is as readily distinguished by the broad depression on one side of the apex, with the narrow slit in the bottom for the protrusion of the peduncle.

Fig. 198.

Trematis terminalis.

Fig. 198 represents a ventral valve of the *Tremalis terminalis* with a marginal apex.

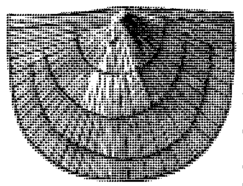
Strophomena. The shell *Strophomena* is semi-circular, widest at the hinge line, concavo-convex depressed, radiately striated; area double; ventral valve with an angular notch, progressively covered by a convex pseudo-deltidium; umbo depressed, rarely (?) perforated, in young shells, by a minute foramen; muscular depressions four, central pair narrow, formed by the adductor; external pair fan-like, left by the cardinal and pedicle muscles; *dorsal* valve with a bi-lobed cardinal process, between the dental sockets, and four depressions for the adductor muscles.

There are no apparent brachial processes in the dorsal valve of Strophomena, and it is possible that the spiral arms may have been supported at some point near the center of the shell. The valves are nearly flat until they approach their full growth; then they bend abruptly to one side.

Strophomena alternata (Con.) is broadly semi-oval; length and breadth about as 12 to 15; hinge line, in perfect specimens, a little longer than the width of the shell, slightly reflected at the extremities, which sometimes become short acute ears; cardinal area narrow, the callosity of the ventral valve nearly filling the triangular foramen of the dorsal valve; beak uniformly perforated with a minute circular opening; dorsal valve depressed convex, sometimes more convex in the middle, suddenly deflected near the margin and flattened towards the cardinal line; ventral valve concave, gradually, or sometimes suddenly inflected towards the basal margin; surface marked by fine rounded radiating striæ, which alternate at unequal intervals with coarser ones; striæ increasing in number towards the margin of the shell, crossed by fine elevated concentric lines and a few imbricating lines of growth.

In this species the striæ are usually of two sizes, the coarser and more elevated ones having from four to six finer ones between; the latter increase in number as they recede from the apex, and one of them, in the center of the fascicle, becomes enlarged, and was above the others. The characteristic developments of the shell depend on the circumstances of its existence, and the nature of the sediment. There are other differences which must be due to other causes beyond our knowledge. The age of the shell also exerts considerable influence upon its external form. The young ones, or those of medium size, are usually symmetrical shells, moderately convex, and gently curving towards the base. The striæ in such individuals are distinctly in fascicles of four to six, separated by stronger and more elevated single ones on either side; as the shell increases, this uniformity in the arrangement often disappears, and the striæ appear of uniform size, or alternate irregularly. The concave or ventral valve, particularly in old specimens, has the striæ nearly uniform in size.

FIG. 199.



Strophomena alternata.

Fig. 199 represents rather a small specimen of *Strophomena alternata*, but one which presents the characters of the species very well. The observer will notice the elevated striæ, and the gradual enlarging of some of the striæ as they recede from the apex. This very common species has been collected at all the prominent localities of Trenton fossils, viz; at Larrabee's Point in Shoreham, Frost's landing in Bridport, McNeil's Point, at the north end of Isle La Motte, and in S. Hero and Grand Isle.

Leptæna is perhaps a subgenus of *Strophomena*. It has the valves regularly curved; the dorsal are concave, thickened, and the muscular impressions are elongated.

Leptæna sericea (Sowerby), is the only species of this genus yet found in Vermont. It is semi-oval: length usually somewhat more than half the width on the cardinal line; cardinal line extended a little beyond the sides of the shell; dorsal valve convex in the center, deflected at the edge; ventral valve concave (nearly flat Sow.); surface marked by fine striæ, which are even and uniform, or alternating with stronger ones; striæ increasing in number towards the margin, granulate or papillose, crossed by a few lines of growth; surface shining.

This beautiful and abundant little shell is readily distinguished by its almost perfectly semi-oval form, with fine papillose striæ alternating with larger ones; the latter are often obsolete, and the surface appears uniformly striated.

Fig. 200 represents one valve of the *Leptæna sericea*, upon which appear equal striæ and a few concentric lines of growth. This species is found in great abundance in the Trenton limestone, at Larrabee's Point in Shoreham, at McNeil's Point in Charlotte, at Grand Isle, at South Hero, and at the north end of Isle La Motte. Some of the specimens from Larrabee's Point are the finest, because the shells have been partly calcined by exposure to the heat of a furnace.

FIG. 200.

Leptæna sericea

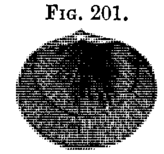
Orthis. The shell of the Orthis is transversely oblong, radiately striated or plaited. biconvex, hinge line narrower than the shell, cardinal process simple, brachial processes tooth-like, prominent and curved.

The *O. testudinaria*, (Dalm), is suborbicular, plano-convex; cardinal line straight, shorter than the width of the shell; dorsal valve convex, much elevated towards the beak, often with an elevated ridge down the center; beak small, slightly incurved; ventral valve flat, or with a longitudinal depression along the center, which often produces an emargination in front; cardinal area small; foramen small, triangular; surface covered with fine striæ, which bifurcate towards the margin, and are crossed by elevated thread-like lines, giving them a crenulated appearance.

This species is somewhat variable. Most of the specimens from the north-east have a regularly depressed convex dorsal valve, with a flat or sometimes slightly convex ventral valve; while shose from the west have very frequently an elevated longitudinal ridge on the dorsal valve, and a depression along the flat or ventral valve.

Fig. 201 is intended to represent the common appearance of the *Orthis testudinaria*. This species is found in all the localities in which the preceding species occurs. The *Orthis testudinaria*, and *Leptæna sericea* are the most common fossils of the Trenton limestone.

FIG. 201.

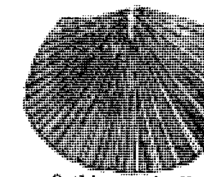


Orthis testudinaria

Orthis pectinella (Con.) The shell of this species is suborbicular or obtusely semi-oval, wider than long in the proportion of about 9 to 12; cardinal line extended, equal to or less than the greatest width of the shell, slightly deflected at the extremities; area moderately large and well defined; shell resupinate, or the area and foramen being principally on the flatter side, or partially common to both; dorsal valve sub convex near the beak, with flat sides and a broad depression along the center, which is distinct in front; ventral valve regularly convex most prominent in the center; beak extending only to the cardinal line; surface marked with from 22 to 30 prominent rounded radii, which are equal to the spaces between; radii simple, or bifid and trifid toward

the margin, crossed by small elevated concentric lines. A prominent distinguishing trait of this shell is its resupinatè character, placing the area and foramen essentially on the dorsal valve, which is nearly flat, while the ventral one is convex.

FIG. 202.



Orthis pectinella.

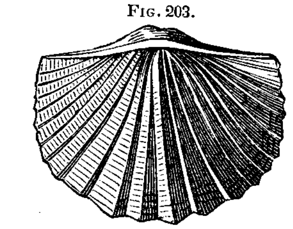
Fig. 202 represents the ventral or convex valve of the *Orthis pectinella*, having radii which are simple or nearly so. A specimen of this species in the State Cabinet is from Isle La Motte, but without specification of thè rock from which it was taken. Another specimen of it was collected by us from the Black River limestone at the island in Button Bay.

Orthis lynx (Hall.) Shell scarcely transverse, varying from semi-elliptical to subquadrate and globose, often nearly as thick as long; length and width as 5 to 9, or equal; cardinal line often exceeding the width of the shell, and usually extended into short, acute ears, or rounded at the extremities; area common to both valves, as also the foramen; ventral valve more gibbous than the dorsal valve; surface marked with strong, angulated, longitudinal plaits, about three to four of which mark the sinus, and four to five the elevated medial lobe; transversely ornamented by concentric or flexuous elevated subimbricating lines, which are very obvious on the lower half of the shell, becoming very distinct in front, and, in perfect specimens, continuing nearly to the beak. Examined with a magnifier, the surface is covered with very fine granulations, like those in some specimens of recent *Terebratulæ*.

It is impossible to assign any definite form and proportions to a shell as variable as this species. It is greatly influenced by local circumstances, especially varying in different regions of the country. The species in the eastern part of the American continent presents the following characters in its different stages of growth and development. In the young shell, there first appears three plaits in the sinus of the dorsal valve, with four on the corresponding medial lobe of the ventral valve; these four becoming two about one-half or two-thirds of the distance from the base to the beak. As the shell grows older, another plait is developed on one side of the sinus, and a corresponding one on the medial lobe; but the five thus developed become two before reaching the beak. In the larger specimens of the New York type there is a fifth plait developed in the sinus, with six upon the corresponding medial lobe. The outer one on each side unites with the adjoining one about half way to the beak, thus making four plaits on the medial lobe, which finally unite in two before reaching the beak. The additional plaits of the medial lobe are developed laterally by a division of the outer one, which takes place at nearly regular intervals corresponding to the increasing size of the shell. The lateral plications in the sinus likewise disappear towards the beak, not by uniting with the adjoining ones as on the opposite valve, but by gradual diminution till they are lost in the surface of the shell. The plications on each side of the medial lobe and sinus increase in like manner by the development of additional ones towards the margin of the shell; and from seven, the number usual in the smallest shells, they increase to ten or eleven, the greatest observed number in any specimen presenting the characters here given; the increase of lateral ones always keeping pace with the development of additional ones in the sinus and medial lobe.

Fig. 203 represents rather a large specimen of the *Orthis lynx*. It is found at McNeil's Point, Larrabee's Point, north end of Isle La Motte, and probably at all important localities of Trenton limestone fossils in Vermont.

FIG. 203.



Orthis lynx.

SHELLS OF ACEPHALOUS MOLLUSKS.

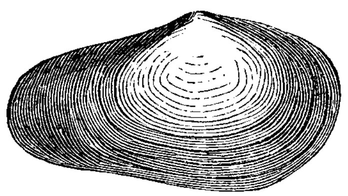
Tellinomya (Hall.) The shells of this genus are equivalve, inequilateral, somewhat compressed below, but becoming gibbous at the umbones; umbones not angular; outline of the shell curved, without angular ridges; shell thin, closely laminated; hinge without visible teeth or crenulations; muscular impressions two in each valve, near the dorsal margin, often apparently gaping at the posterior extremity.

Tellinomya levata (Hall.) Somewhat obliquely ovate or subrhomboidal, gibbous; anterior extremity broad, rounded; posterior side narrower and somewhat obliquely truncated; umbones usually about one-third of the length from the anterior extremity, elevated and incurved; cardinal line slightly curved; crenulations extending nearly twice as far on the posterior as on the anterior side; surface obscurely marked with concentric lines; muscular impressions visible near the anterior and posterior extremities.

This shell has been found in Trenton limestone at South Hero and Grand Isle.

Tellinomya nasuta (Hall.) Shell transversely elongated, inequilateral; anterior extremity rounded; posterior extremity greatly extended into a kind of beak which is narrowed and compressed, contracted on the base by a shallow sinus; umbones prominent, rounded; shell thin; surface marked by fine concentric lines. The muscular impressions are strongly marked upon the cast, and the umbones are more obtusely angular; there is no evidence of teeth or crenulations. This shell is readily distinguished by the prolonged posterior extremity, which is obliquely truncated and constricted by a sinus on the base. This character is more conspicuous on the cast than in the perfect shell; the anterior portion of the shell is more gibbous, and regularly rounded at the extremity.

FIG. 204.



Tellinomya nasuta.

Fig. 204 represents the right valve of *Tellinomya nasuta.* It is a rare species, and is found in connection with the preceding.

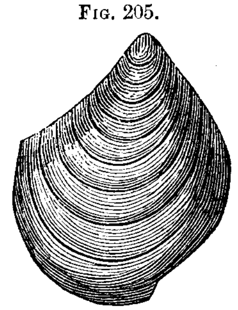
Modislopsis (Hall.) The shell of this genus is equivalve, inequilateral, elongated, becoming broader posteriorly; umbones near the anterior extremity, which is marked by a single strong muscular impression as in *Modiola.* A sinus often extends from the anterior side of the umbones, obliquely backwards, leaving the anterior portion separated as a kind of lobe. Surface marked by fine concentric striæ; shell thin.

An undetermined species of *Modislopsis* was found in Trenton limestone in South Hero.

Ambonychia (Hall.) Equivalve, inequilateral, compressed, alate or subalate posteriorly, obtuse and abruptly declining or curving downwards on the anterior margin. General form somewhat obliquely ovate, gibbous or inflated towards the umbones on the center of the shell; cardinal margin very oblique, or approaching a line parallel to the direction of the umbones, which are often incurved at the extremity, and equal, or project beyond the line of the anterior extremity; surface marked by more or less prominent concentric striæ, strong undulations, or fine radiating striæ. Muscular impressions large, one in each valve.

The *Ambonychia undata* (Con.) is the only species of this genus which we have collected in Vermont. It is obliquely ovate or subrhomboidal, with the base rounded, ventricose; anterior margin obtuse, straight above and curving below; posterior margin compressed, scarcely alate above; cardinal line straight, oblique; umbones ventricose, elevated, narrowing above and scarcely incurved, with the extremities bending forward; surface with broad, smooth, concentric undulations, which curve downwards more abruptly on the center of the shell; anterior side scarcely concave below the beaks; no definite lunette.

FIG. 205.



Ambonychia undata.

Fig. 205 represents an imperfect right valve of the *Ambonychia undata.* It occurs in Vermont upon the Island of South Hero. Future investigations may refer this species to some other genus, as the interior of the shell is yet undetermined.

GASTEROPOD MOLLUSKS OF THE TRENTON LIMESTONE.

Maclurea Logani (Salter.) This shell, when perfect, is fully three and a half inches wide, and is conspicuous for the great flatness of its lower or whorled side, and the fewness of its whorls, for, if we except one or two minute inner ones, there are but two or three distinct whorls, which diminish so rapidly in breadth that the outer is at least thrice the width of the preceding ones in succession, and greater than that of all the inner whorls taken collectively; in *M. magna* it is greatly less than these. The whorls are very gently convex between the sutures, which are sharply marked though not deep, and are closely striated by regular sharp-arched lines of growth. The sides of the whorl are steep, pyramidal, the depth exceeding the width of the whorl, and are furrowed by a number of deep grooves, sometimes sixteen or seventeen, a few of which are interlined with smaller ones. Occasionally seven or eight only are present, or a deep one occurs at a short interval; but this may be the result of injury.

The base itself is smooth, or with faint concentric striæ only, and the umbilicus (so called) rather abrupt and very narrow, not above one-third the width of the whorl, and with a rounded edge. The shell is solid, nearly a line thick.

The most singular part of the shell is its operculum, sometimes seen fixed in its normal position, and at other times drawn within the shell. It is exceedingly solid, the successive layers are sub-spirally arranged, tiling over one another, and are antiquated in growth. The nucleus is near the inner and lower angle of the mouth; in old shells it is pushed further out, and becomes the apex of a very solid short cone, one surface of which lies close upon the inner flat surface of the whorl. Two curved furrows radiating from the nucleus, divide the surface into three areas, less distinct in the mature shell. Inside, a thick compressed process takes its rise beneath the nucleus, retaining its place near the inner angle of the mouth, even in the adult shell, when the nucleus itself has removed further out. The process is as broad as long, and on its oblique free margin it is roughened and grooved, for the attachment of nucleus. Another attachment, similar, but much less prominent, exists at the inner and upper angle, and a line of minute prominences partially connects the two.

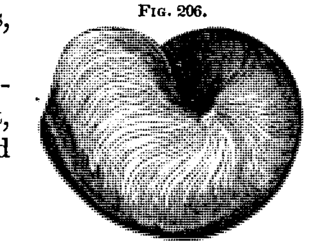
This species is closely allied to the *M. magna* of the Chazy limestone. It occurs in the Trenton limestone at Highgate Springs. We believe this fossil has as yet been found only on the Ottawa River in Canada, and in Vermont.

A shell related to the genus *Euomphalus* was collected at South Hero from the Trenton limestone, but was not sufficiently distinct to reveal its specific characters. We believe that the genus *Euomphalus* is not found in the Trenton limestone elsewhere.

Bellerophon (Monfort.) Shell symmetrically convoluted, globular or discoidal, strong, few-whorled, whorls often sculptured; dorsally keeled; aperture sinuated and deeply notched on the dorsal side.

Bellerophon bilobatus (Sow.) is involute, subglobose; height and width about equal; aperture bilobate, large, subreniform; surface marked by fine striæ, which, ascending from the umbilicus, form a broad arch on the side of the shell, and, bending downwards, meet in an abrupt curve on the dorsal line.

FIG. 206.



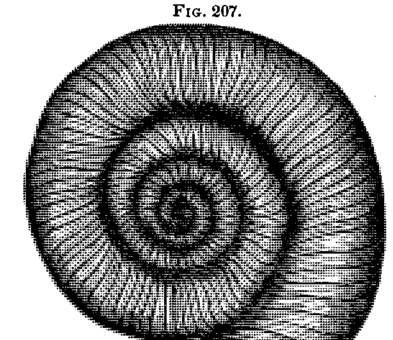
This species is represented in Fig. 206. It is abundant in the Trenton limestone, occurring at almost every locality. We have seen it at Larrabee's Point, at McNeil's Point, in Bridport near the village, in South Hero, at the north end of Isle La Motte, and at Highgate Springs.

Cephalopod Mollusks in Trenton Limestone.

Trocholites, (Con.) Shell discoidal; whorls close or separate; last chamber produced in a straight line; siphuncle central. This genus is probably synonymous with *Lituites.*

Trocholites ammonius (Con.) This species was found by Prof. Adams in Vermont, in Addison County. It is discoidal; volutions in the same plane, about four, rounded, slightly concave on the ventral side, gradually enlarging in size towards the aperture, which is slightly expanded; surface marked by lamellose, irregular and oblique transverse striæ or ridges, between and upon which are finer lamellose striæ covering the outer surface, and giving it a peculiar textural or netted appearance; striæ meeting in an arch upon the back; septa direct, or slightly undulated on the dorsal side; outer chamber large; siphuncle ventral.

FIG. 207.



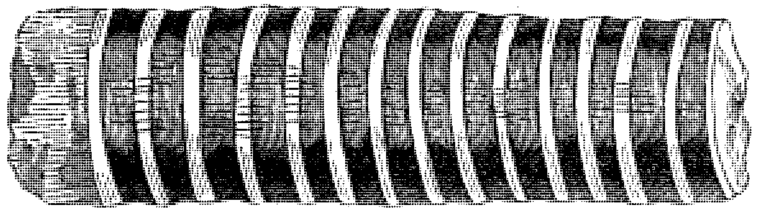
Trocholites ammonius.

Fig. 207 represents a large specimen of *Trocholites ammonius,* which preserves the lamellose surface.

Orthoceras (Breyn.) Shell straight; siphuncle central; aperture sometimes contracted. The *orthocerata* are the most abundant and widespread shells of the older rocks, and have attained a larger size than any other fossil shell. Specimens have been found twelve feet long and a foot wide. Such carnivorous monsters must have been in the silurian seas what sharks are in alluvial oceans.

O. vertebrale (Hall.) This shell is cylindrical, very gradually tapering, annulated with abruptly elevated angular ridges, which are distant from each other about one-fourth the diameter of the tube, slightly arched upon the back, and direct on the ventral side; surface marked by strong longitudinal striæ and finer transverse ones, giving it a cancellated appearance; siphuncle apparently central or subcentral.

Fig. 208.

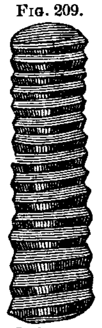


Orthoceras vertebrale.

Fig. 208 represents the ventral side of a fragment of the *O. vertebrale.* We have found this species only in the Black River limestone of Isle La Motte.

O. anellum (Con.) This shell is elongated, very gradually tapering, annulated by prominent sharp slightly sinuous ridges which are distant about one-fourth the diameter of the shell, longitudinally marked by fine crowded wrinkled striæ; septa moderately convex; siphuncle eccentric, but not marginal; section circular.

Fig. 209.



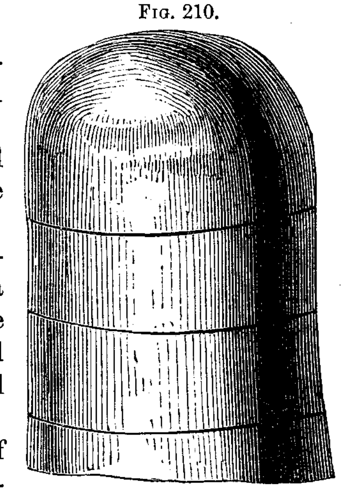
Orthoceras anellum.

This species is readily distinguished from all others by its angular approximative angulations, which are sharper and more elevated than those of any other species.

Fig. 209 represents a fragment of the septate portion of the shell of the *O. anellum.* It is found with the preceding species in Isle La Motte.

O. amplicameratum (Hall.) Teretely cylindrical, extremely elongated, very gradually tapering; outer chamber profound; septa distant about one-third of the diameter, very convex; siphuncle eccentric, small; surface (?) section circular. This species is distinguished from all others in the Trenton limestone by its great length and very gradual diminution from the larger extremity, and the distant and very convex septa.

Fig. 210.

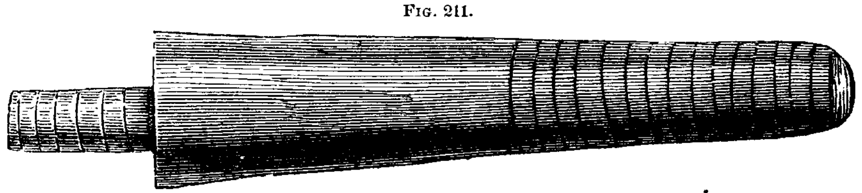


Orthoceras amplicameratum.

Fig. 210 represents a fragment of the septate portion of a large shell of the *O. amplicameratum.* The specimen was found in South Hero, in Trenton limestone.

O. strigatum (Hall.) Elongated, teretely cylindrical, gradually tapering; outer chamber large; septa distant about one-fifth the diameter of the shell, very convex; siphuncle small, central; surface marked by flexuous elevated longitudinal lines, which are indistinctly visible on the cast.

Fig. 211.



Orthoceras strigatum.

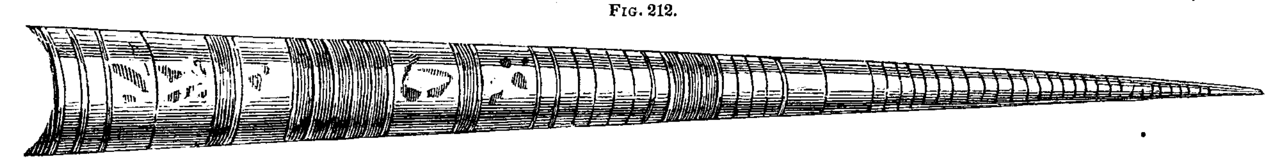
Fig. 211 represents a fragment of a large specimen of this species. About twenty of the chambers are preserved, as well as a large part of the outer chamber. There is also present a small septate tube within the open extremity. This occurs in the upper part of the Trenton limestone, in Grand Isle.

O. multicameratum (Con.) Extremely elongated, slender, very gradually tapering to an acute point;

surface apparently smooth, or girt with slight undulations; septa thin, gently arched, distant from one-fourth to one-twelfth the diameter; siphuncle a cylindrical ventral tube; outer chamber very deep.

Fig. 212 represents a fragment of the shell of the *O. multicameratum.* It is found in the Trenton limestone at Highgate Springs, and in New York it is confined to the Birdseye limestone.

Fig. 212.



Orthoceras multicameratum.

Endoceras (Hall.) This is a provisional name to include those species of *Orthocerata* which have a large siphuncle, mostly lateral or eccentric, marked or ridged on the outer surface by the septa, which, from their oblique direction, give it the appearance of a tube with spiral lines. Within this siphuncle are one or more very elongated conical tubes, often one within another to the number of four or five.

Endoceras proteiforme (Hall.) General form cylindro-conical, more or less elongated, often compressed, tapering somewhat unequally in different specimens; young specimens terminating in an extremely acute point; surface marked by distinct transverse striæ, which usually appear like narrow, subimbricating bands, with one edge well defined and more elevated than the other, more or less distinctly striated longitudinally; striæ varying from extreme tenuity to distinct, elevated, thread-like lines; section circular; septa distant from one-fifth to one-fourth the diameter; siphuncle eccentric or submarginal.

There is a great variety in the forms of this species. The old and young of the species are generally so united as to form but one shell within another.

Plate XII, Fig. 1, represents the finest specimen of the *Endoceras proteiforme* which we have found in Vermont. The long, tapering, slightly curved part of the specimen is the embryo tube; and the larger part is the parent shell. The septæ are preserved in both.

This species is rather abundant in the Trenton limestone in Grand Isle, South Hero, and McNeil's Point in Charlotte.

TRILOBITES OF THE TRENTON LIMESTONE.

Trilobites are very abundant in the Trenton limestone, and furnish the best tests for its identification of strata in different localities. Certain species of *Trinucleus*, *Ceraurus*, *Asaphus*, and *Ogygia* are unknown either above or below this rock. Articulate animals, like trilobites, are better tests for the indentification of strata than most mollusks; because the more highly organized the animal, the less is his vertical range.

Asaphus canalis (Con.) The *Isotelus gigas* (Dekay) is now referred to the *Asaphus canalis*, by the best authorities.

Its general figure is oval-oblong, with the sides rather straight; buckler in the form of a spherical triangle, obtuse or more or less rounded at the posterior extremities; cephalic shield convex in the middle, rapidly descending in front and at the sides, margined by a narrow elevated rim or border; eyes sublunate, prominent, subfedunculated, strongly supported on the inner and concave side, by a projection of the glabella; facial suture continuing from the center of the front, nearly parallel to the margin, until in a line with the eye, where it turns backward, and leaving the eye upon the maxillary portion, turns outwards and backwards, coming out at the base of the shield distant from the angle; thorax with eight articulations, the middle lobe about once and a half the breadth of the lateral lobes, the longitudinal grooves continued slightly into the buckler, and more distinctly into the caudal shield; segments of the middle lobe flat above; those of the lateral lobes, with a groove on their upper surface, extending nearly half way to their extremities; caudal shield of nearly the same form as the buckler, presenting externally some evidence of a trilobite character, sharpened at its upper lateral angles, and having a single transverse groove on each of the lateral lobes extending from the axis more than half way to the margin; entire surface finely punctulated.

When the crest of the buckler is removed, a narrow shallow groove is visible at the base.

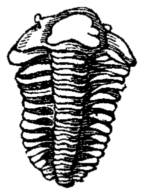
In young specimens the caudal extremity is more pointed, and presents the marks of eight anchylosed articulations; in older specimens, these increase in number, but the external crust presents scarcely any traces of them. When the crust is removed, however, they are often very distinct.

Plate XII, Fig. 4, represents a specimen of *Asaphus canalis*, natural size, from Porter's Landing in Grand Isle. This was the finest locality for the species, and for many other species of fossils that we have seen in any part of the State. The *A. canalis* was found elsewhere at Larrabee's Point, Frost's Landing in Bridport, half a mile north of Chimney Point in Addison. McNeil's Point in Charlotte, South Hero, Grand Isle, north end of Isle La Motte in several places, and at Highgate Springs.

Calymene. The form of the shield is oval; the head larger than the pygidium, and the latter is about one half as large as the thorax; the crest is granulated; the front lobe of the head projecting, the lateral lobes of the glabella are globular and separated from the middle part by deep winding furrows, which nearly isolate them, the main furrows being divergent from the front; the eyes are reticulated, but not well developed; the thirteen segments of the thorax are angulated, and the ribs or lateral lobes are bent and rounded at the extremities; the pygidium is convex and rounded, and its center lobe distinct and narrower thanthe lateral lobes.

Calymene senaria (Green.) Buckler semi-circular or sublunate, regularly rounded in front, or slightly projecting in front of the glabella, with a distinct thoracic ring at the base; posterior angles subacute or rounded; glabella separated from the cheeks by a deep broad groove, wider behind or often of nearly equal width throughout, with three tubercles or lobes on each side, the anterior one often obscure; cheeks triangular; eyes truncato-conical, situated a little outward from the inner edge of the cheek; facial suture terminating nearly in front of the eye; thorax with thirteen segments, those of the lateral lobes with a deep groove extending from the base more than half way to the extremities; caudal shield small, with seven segments in the middle lobe and five in each lateral one, the latter with an impressed line or shallow groove the whole length.

Fig. 213.



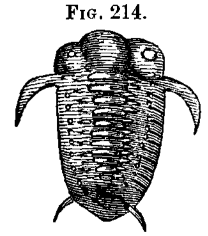
Calymene senaria.

Fig. 213 represents a small specimen of the *Calymene senaria.* It is found in most of the localities of Trenton fossils in Vermont, particularly at Larrabee's Point, Chimney Point, Frost's Landing, NcNeil's Point, South Hero, Grand Isle, and Isle La Motte (north end.)

Ceraurus. Large or small; form somewhat triangular; pustulated, granulated, and spinous; cephalic shield crescentiform; thoracic rings eleven; glabella quadrangular and four-lobed; the furrows forming the lobes extend transversely one-fourth across them; the main furrow, separating them from the cheeks, are nearly in a line with those on each side of the axis; eyes distant, granulated; cheeks triangular.

Ceraurus pleurexanthemus (Green.) Buckler crescent form, with a prominent connate articulation at the base, and the posterior angles extended into long curved spines; eyes small, distant, sublunate, granulated (not reticulated); glabella clavate, more or less convex, deeply four-lobed on each side, leaving the front one broader; thorax with eleven articulations; caudal shield with four (scarcely five) anchylosed articulations in the axial lobe, and three on each lateral lobe, the upper of these articulations thickened and extended into a long curved spine, the others terminating in blunt points; surface entirely papillose or granulated, the buckler with scattered larger tubercles; two ranges of small papilose tubercles along the central lobe, and three ranges of mammillary tubercles on each lateral lobe; labrum ovate, attached to the front margin of the glabella by a straight suture. No single specimen, yet found, presents all these characters, but the description is derived from fragments of different individuals.

Fig. 214.



Ceraurus pleurexanthemus.

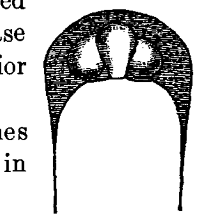
Fig. 214 represents a nearly entire specimen of this species, but the maxillary portions are obscure. Prof. Adams found this specimen in Vermont, but his notes leave it uncertain whether it occurs in Shoreham, Bridport and Addison, or in only one of these towns.

Trinucleus. Form a short ellipse; surface smooth; head largely developed, and bordered with a perforated

limb, which terminates in long spines; cephalic shield composed of three prominent convex lobes; the furrows of the glabella converging towards the axis; thorax with six rings; those of the pygidium variable.

Trinucleus concentricus (Eaton.) Buckler semi-circular or subcresent form, the posterior angles produced into long, slender, straight spines; glabella very prominent, finely granulated, produced posteriorly into a short spine; cheeks prominent, finely granulated; marginal fillet marked in front by three, four or five rows of deep rounded pores or punctures; these rows increase by one or two additional ones on the sides of the shield, and towards the lateral posterior angles are often irregularly scattered.

Fig. 215.



Trinucleus concentricus.

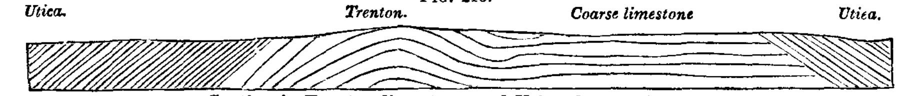
Fig. 215 represents the cephalic shield of this species, together with the slender spines from the posterior angles. We have seen no specimens of the thorax or caudal shield, in the Trenton limestone, though the cephalic shield is very abundant.

This species is widely distributed in the Trenton limestone of Vermont. It has been seen at Larrabee's Point in Shoreham, Frost's Landing in Bridport, near Bridport village, near Chimney Point in Addison, in the Trenton limestone at the base of Snake Mountain, in the east part of Ferrisburgh, Mc Neil's Point in Charlotte, at Grand Isle, north part of Isle La Motte and at Highgate Springs. A bowlder of this rock was found in Sudbury, containing this species, which must have been transported several miles.

Geological Position and Equivalency.

The Trenton limestone lies between the Utica slate and the Chazy limestone. Its position has been noticed upon the Snake Mountain section, but we have another section in Fig. 216, to illustrate its relations to the Utica slate. Its connection with the Chazy limestone is given in Fig. 178.

Fig. 216.



Section in Trenton limestone and Utica slate, at Panton.

Fig. 216 was originally sketched by Prof. Thompson. It is in the extreme northwest corner of Panton, upon the shore of the lake. The beds of the limestone are quite thick, so much so at times as to be nearly destitute of any marks of stratification. The slate is considerably broken, but it contains distinct graptolites of the Utica slate.

UTICA SLATE.

It is difficult to distinguish between the Utica slate, and the shales of the Hudson River Group in Vermont, except by their fossils: hence it is not unlikely that the distinctions between them, which we have given, are not always correct. As we had very few fossils to judge from, we were obliged to separate the two rocks, mostly geographically and stratigraphically. In the main it will be correct. We are not sure that there is sufficient difference between these two rocks in nature, to separate them into distinct groups. If so, the importance of a precise boundary line between them upon the map will be slight.

Lithological Characters.

In this respect there is great uniformity. The Utica slates are the continuation of the calcareous shales of the Hudson River Group downwards, until they meet the slaty limestone of the Trenton limestone. There are two principal varieties in Vermont:

1. Black calcareous slate. 2. Thin beds of limestone, containing nodules of pyrites. 3. Glazed shales, having an anthracitous lustre.

The common variety greatly resembles the shales of the Trenton limestone; differing from them principally by being firmer, and exhibiting a double system of joints, which are often filled with seams and veins of calcite. The common variety can be seen at any exposure of the formation, from Canada to New York. The second variety is best exhibited upon the islands in Lake Champlain. The limestone beds are rarely more than six inches in thickness, and generally are from one to three inches thick. The nodules of iron pyrites greatly resemble fossils, and in many cases are doubtless altered organic remains. They can be found at almost any ledge of this rock, in North Hero, and in the east parts of Grand Isle and South Hero. In the Cabinet, Nos. $\frac{12}{179}$ to $\frac{12}{181}$ are specimens of these nodules of pyrites.

The veins of calcite constitute a marked feature of this rock. There are three varieties of them: the large veins or dikes; the smaller ones, that twist and branch in every direction frequently like the branches of a tree; and thirdly, those small veins that occupy the cleavage seams, and are parallel to one another over large areas.

The first class are numerous in the north part of Grand Isle, near Mr. Hurlburt's house. The largest is two feet wide. They cross the strata at almost every angle—more usually crossing at right angles to both dip and strike—and have disturbed the original position of the strata in their immediate vicinity. The substance of the veins is pure white calcite. The second kind of veins is exceedingly abundant upon most of the islands in the north part of Lake Champlain. We would specify the southwest part of North Hero as a locality particularly abounding with them. For half a mile, along a cliff twenty-five feet high, these white veins show themselves, ramifying among, crossing or running along with the strata, and occasionally interrupted by veins of a newer age, crossing them per force. In many seams, the calcite had been pressed by dislocation so much that it was smoothed, and the glazed surfaces resembles the *slickensides* of metallic veins. A fine locality of the third variety (which is perhaps Hudson River slate) is in the cliff on the lake shore, in the northwest part of St. Albans. Several rods square have these veins parallel to one another, and instantly attract the attention of the passer by, because of their beauty.

Divisional Planes.

The most conspicuous divisional planes in the Utica slate are those of cleavage, and these are generally inclined at a high angle. Jointed planes occur, but we have measured none of them, and cannot say what their general position is.

Sometimes the cleavage planes are so prominent that the attention of the observer is entirely occupied with them, to the neglect of the planes of stratification; and again the planes of stratification have entirely disappeared. A metamorphic action, adequate to produce an incipient crystallization, would totally obliterate the planes of the strata. We give a list of the positions of the cleavage planes observed in the Utica slate:

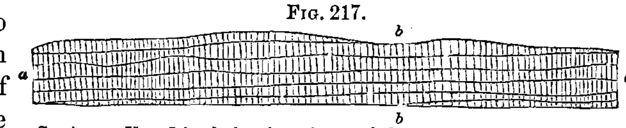
Locality.	*Strike.*	*Dip.*	*Observer.*
Shoreham, west part,	N. 10° E.,	45° E.,	A. D. H. and C. H. H.
Bridport, southwest part,	N. 66° E.,	29° E.,	C. H. H.
Addison, Cobble Hill,	N. 20° E.,	75° E.,	C. H. H. and A. D. H.

Addison, Cobble Hill,	N. 10° E.,	60° E.,	C. H. H. and A. D. H.
Charlotte, northwest part,		58° E.,	C. H. H.
Shelburne, southwest part,	N. 5° E.,	45° E.,	C. H. H.
Shelburne, Nash's Point,		41° E.,	C. H. H.
Appletree Point, Burlington,	N. 70° E.,	85° E.,	C. H. H. and E. H., jr.
North Ferrisburgh,	N. 40° E,	50° E.,	C. H. H.
Colchester Point,		50° E.,	C. H. H. and E. H., jr.
Hog Island, near do.,		90° E.,	C. H. H. and A. D. H.
Rock Dunder,	N. 45° E.,	73° E.,	C. H. H. and A. D. H.
Juniper Island,	N. 25° E.,	70° E.,	C. H. H.
Grand Isle, east part,		30° N. E.,	C. H. H.
Grand Isle, east part,	N. 42° E.,	30° S. E.,	C. H. H.
South Hero, Kibbe's Point,	N. 35° E.,	56° E.,	C. H. H.
Isle La Motte, east side,	N. 65° E.,	60° E., etc.,	C. H. H.
North Hero,	N. 38° E.,	74° E.,	C. H. H.
North Hero, Carrying Place,		30° E.,	C. H. H.

The angles between the dip of the cleavage planes and of the strata, in all these cases, will average about thirty-five or forty degrees; the limits of variation are from fifteen to ninety degrees.

Fig. 217 represents the manner in which these two kinds of planes occur upon *Hog Island*, a small island off Colchester Point. The name is rather an unpleasant one, and we would therefore propose for it a new name, first suggested by Profs. Adams and Thompson, in their note books—namely, *Yew Island*,—so called from the great number of yew trees found upon it. The cleavage planes are the most conspicuous of the two sets, and very greatly resemble the true planes of bedding; but the alternations of different materials in the strata, though faint, yet satisfy the observer that they are the true dip. *a*, *a*, represent the planes of stratification, and *b*, *b*, those of cleavage.

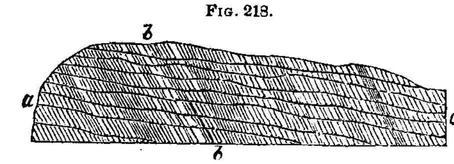
Fig. 217.



Section on Yew Island showing planes of cleavage and of stratification.

This is one variety of cleavage. Another is given in Fig. 218, representing a case at Kibbe's Point, in South Hero, where the angle between the two kinds of divisional planes is a trifle less than fifty degrees, the previous figure showing a difference of 88°.

Fig. 218.



Section at Kibbe's Point, in South Hero.

In all these cases the strata seams are readily distinguished by their gentle irregularities; while the cleavage planes are always as true as if the hand of man had drawn them with rule and compass. The strata here dip from four to eight degrees easterly, while the cleavage planes dip fifty-eight degrees in the same direction.

STRIKE AND DIP OF THE STRATA.

Locality.	*Strike.*	*Dip.*	*Observer.*
West Haven, west of post-office,	N. 30° E.,	50° E.,	C. H. H. and E. H., jr.
Shoreham, west part,	N. 10° E.,	45° E.,	C. H. H. and A. D. H.
Shoreham, Lake Shore,	N. 24° E.,	16° E.,	C. H. H.
Bridport, southwest part,	N. 66° E.,		C. H. H.
Bridport, west part,	N. 35° E.,	9° W.,	C. H. H.
Bridport, northeast corner,	N. 25° E.,		E. H., etc.
Addison, west part,	N. 45° E.,	25° N.W.,	C. H. H.
Addison, Snake Mountain,	East of north,	38° E.,	C. B. A.
Addison, Snake Mountain,	East of north,	15° E.,	E. H., etc.
Addison, Lake Shore,	N. 45° E.,	12° N.W.,	C. H. H.

Addison, near Elm Point,	N. 32° E.,		Z. T.
Ferris Island,		2°–4° N.,	Z. T.
Panton, Arnold's Bay,		Southerly,	C. H. H.
Ferrisburgh, Button Bay,	N. 18° E.,	15° W.,	C. H. H.
Ferrisburgh, Button Bay,	N. 20° E.,	20° W.,	Z. T.

"Utica slate continues south of this point. North of Adam's Bay, in Panton, it has a northerly dip, but on the south side of the bay it is nearly horizontal, soon dipping slightly to the southeast." Z. T.

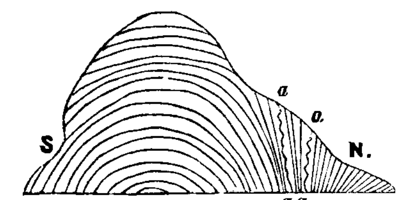
North Ferrisburgh,	N. 4° E.,	13° E.,	C. H. H.
Charlotte, northwest part,		10° northerly,	C. H. H.
Shelburne, southwest part,	N. 5° E.,	15° E.,	C. H. H.
Shelburne, Nash's Point,		15° E.,	C. H. H. and A. D. H.
Rock Dunder,	N. 45° E.,	40° W. and 25° E.,	C. H. H. and A. D. H.
Juniper Island,	N. 25° E.,	12°–38° E.,	C. H. H.
Appletree Point,	N. 35° E.,	50° E.,	C. H. H. and E. H., jr.
Appletree Point,	N. 10° W.,	35° E.,	Z. T.
Appletree Point,		8°–10° E.,	C. H. H. and A. D. H.
Colchester Point,		15° E.,	C. H. H. and E. H., jr.
Colchester, near the Point,		15° E.,	C. H. H. and E. H., jr.
Law's Island,		Northerly,	C. H. H.
Yew Island,	N. 38° E.,	9° E.,	Z. T.
Yew Island,		2° W.,	C. H. H.
Ladd's Island,		9° N.,	C. H. H.
South Hero, Kibbe's Point,	N. 35° E.,	4°–8° E.,	C. H. H.
South Hero, Sand Bar,		About 12° E.,	C. H. H.
Grand Isle, east part,		10° N.E.,	C. H. H.
Grand Isle, east part,	N. 42° E.,	9° S.E.,	C. H. H.
North Hero, southeast side,		4°–5° N.E.,	C. H. H.
North Hero,	N. 38° E.,	15° S.W.,	C. H. H.
North Hero, Carrying Place,		12° E.,	C. H. H.
North Hero, southeast corner,		12° N.E.,	C. H. H.
North Hero, southwest part,		4°–5° E.,	C. H. H.
North Hero, southwest corner,		5° N.,	C. B. A.
North Hero, Paine's Point,	N. 47° W.,	4° N.E.,	C. B. A.
North Hero, northwest part,		A little to the west,	C. B. A.
North Hero, one mile south of do.,	N. 20° E.,	10° E.,	C. B. A.
North Hero, two and a half miles south of do.,	N. 35° W.,	40° N.E.,	C. B. A.
North Hero, Pellet's Point,		5° N.E.,	C. H. H.
North Hero, northeast part,		Dips to east and to north,	C. B. A.
Isle La Motte, east side,	N. 65° E.,	60° E.,	C. H. H.
Alburgh, south part,		Small to west,	C. H. H.
Grand Isle, Tobias' Landing,		10° N.E.,	C. H. H.

An inspection of this list shows that in the southern part of the formation, the prevailing dip is to the east; that in the part north of Colchester Point, the usual dip is to the northeast and north; while in Bridport and Addison, a westerly dip prevails. These variations in the two first instances, depend upon the direction of the whole formation; and in the latter case it depends upon its position upon the west side of an anticlinal axis. The magnitude of the dip, in many cases, is due to local causes, or the cleavage planes may have been mistaken for the true inclination.

Rock Dunder is a naked mass of slate, lying nearly midway between Pottier's Point, in Shelburne and Juniper Island. Its circumference, at the surface of the water, on the 28th of July, 1846, was 310 feet, and its height above the water 36 feet; but as there is considerable space around the base of the rock, near the water level, the circumference will vary with the amount of water in the lake.

Rock Dunder and Juniper Island, are remnants of a great belt of Utica slate, that once filled Lake Champlain, connecting with Shelburne on the east, and South Hero on the north. Rock Dunder consists of two folds, as shown in Fig. 220; *a, a*, represent two small veins of limestone running through it. The base of the rock is strewed with large bowlders of Winooski limestone and Laurentian gneiss. The surface of the rock has been whitewashed, but the black color of the slate is more conspicuous than the white color of the wash. It is a favorite resort for flies and musquitoes in the summer; and an alluvial deposit, of considerable thickness, is forming of the skeletons of flies and musquitoes. This deposit would make an excellent fertilizer.

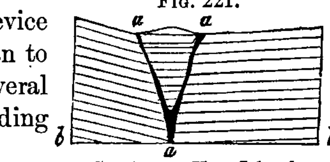
Fig. 220.



Rock Dunder.

Yew island presents at its east end a slight irregularity, as shown upon Fig. 221. The strata dip towards one another, forming a synclinal axis. As the sides of the basin were elevated, the bottom of the axis was broken, and the dark lines, *a,a*, represent the lines of fracture. A portion of the strata has been lifted up, so that it looks like a great wedge, driven into a crevice in the rocks. Below the wedge, there is an opening large enough for a man to crawl into. The water at the level of *b,b*, fills this opening to the depth of several inches. The sides of the opening are smoothed, like *slickensides*, by the crowding of the wedge-shaped mass upwards.

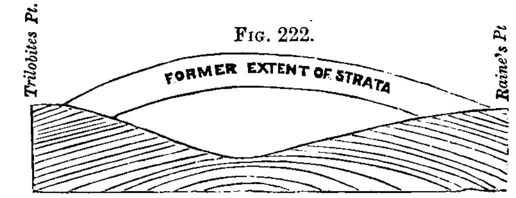
Fig. 221.



Section on Yew Island.

An example of the curvature of Utica slate is given in Fig. 222. It was sketched by Prof. Adams in 1847. It is at Paine's Point, at the southwest part of North Hero. A point adjacent, found by him to abound in trilobites, was christened *Trilobite Point;* and as the point deserves a name, no more appropriate one can be given. The two points are thirty rods distant, and must have been connected together formerly by an arch. The necessity for this arch is said to be very obvious. The height of the points is about twenty-five feet, while the intervening shore is quite low. We have drawn lines to indicate the former extent of the arch.

Fig. 222.



Utica slate, at North Hero.

Range, Extent and Thickness.

There are two ranges of Utica slate in Vermont. The principal one begins at West Haven, passes north through Benson, Orwell, Shoreham, Bridport, Addison, Waltham, Ferrisburgh, Charlotte, Shelburne, thence under Lake Champlain to Juniper Island, Rock Dunder, Appletree Point, Colchester Point, Law's Island, Yew Island, South Hero, Grand Isle, North Hero, the eastern edge of Isle La Motte, and is last seen in Vermont at Alburgh. In Canada the range continues towards Montreal, curving westward south of that city, then turning northeasterly again and running down to the Atlantic Ocean, parallel to the Laurentian rocks north of the St. Lawrence River.

The other range is quite limited. It is found on the west side of an anticlinal in the Trenton and Chazy limestones, in the towns of Addison, Bridport and Panton, and near Split Rock in New York.

The range commencing at West Haven, belongs to that belt which extends northward from Hudson River. As it enters Vermont, it cannot be distinguished lithologically from the shales that follow, of the Hudson River Group; and in this region we have discovered no fossils in either. The shales first appear, in ascending the series above the Trenton, about a mile west of West Haven Post Office. Their inclination is much greater than that of the underlying rocks; hence it is not unlikely that the real dip has disappeared before the obliterating agency of cleavage.

In Benson and Orwell this slate is found immediately overlying the Trenton in both towns, rather more than a mile west of the two villages. Through all these towns its thickness is inconsiderable. At Shoreham, near Larrabee's Point, the thickness increases rapidly. The whole of the southwest part of the town is underlaid by it. From Shoreham it takes a northeasterly direction towards Snake Mountain, and it is recognized near the village of Bridport, and in the northeast part of Bridport near Jesse Craine's house. Here it is under the shadow of Snake Mountain. Along the western base of this mountain it crops out at intervals. It is well exposed at the northwest base of the mountain. From this point it turns eastwardly, following the course of the red sandrock into Waltham.— It can be readily traced by pedestrian geologists along the hill sides of the sandstone range through the east part of Ferrisburgh. At a bridge over Lewis Creek at North Ferrisburgh, there are several exposures of this rock, and its predominant characters may be seen here to advantage, as the ledges are of such easy access. In the south part of Charlotte these measures are concealed, but not in the west and northwest parts of the town, especially upon the banks of Lake Champlain. The localities are numerous, and therefore need not be detailed. In the southwest part of Shelburne, along the coast, Utica slate also appears, but before reaching the middle of the west coast Hudson River shales take their place; the former having passed under the waters of the lake to re-appear in Rock Dunder and Juniper Island. They are displayed again at Appletree Point west of Burlington Center, where Sir W. E. Logan discovered a specimen of *Triarthrus Beckii.* We had discovered previously an imperfect graptolite, and Prof. Thompson had found fossils of this group in fragments of slate along the water's edge, but supposed them to have been transported there by drift agency. The extremity of Colchester Point is tipped with this slate; but most of the rocks in the west part of the town of Colchester are covered with alluvium. The two islands off Colchester Point, Law's Island and Yew Island, as well as Ladd's Island, belong to this range. Allen's Point of South Hero is sandy, but must be underlaid by this slate, as well as the whole of the island, east of a line running from Allen's Point to Tobias' Landing in Grand Isle. The exposures especially noticed were at the Sandbar Bridge, Adams' Bay, Kibbe's Point, Kibbe's Island, Keeler's Bay, Pearl's Bay, Hyde's Point north of Tobias' Landing, and near Mr. Hurlburt's house at the north end of Grand Isle. The whole of North Hero belongs to this range. Several excellent localities of fossils are found upon the western shore, particularly at the southwest corner of the island, at Paine's Point, at Trilobite Point, and much further north at Pelot's Point. The Utica slate is more finely developed upon this island than in any other part of the State. Especially abundant here are the beautiful veins of calcite, the thin beds of limestone, and the curious nodules of pyrites.

Alburgh is entirely composed of Utica slate. At the southeast and southwest shores, ledges of it are numerous and conspicuous; and in the middle of the island, near the track of the Vt. and Canada R. R., it shows itself again. Upon the east side of Isle La Motte, two ledges of this slate appear, in contact with the Chazy and Trenton limestones. It is an unnatural conjunction, and Figs. 173 and 174 illustrate their relative positions.

The second range of Utica slate is of small extent. In the southwest part of Bridport, south of Frost's Landing, it first appears. There is a small anticlinal in the Trenton limestone at Frost's Landing, which brings to view the slate again, in the west part of

Bridport, where the usual graptolites of this rock were found. It is interrupted before reaching Chimney Point by Chazy limestone. It is found again at Elm Point in the west part of Addison. To the north, in Addison and in Panton, it contains the characteristic fossils. A lower limestone in the west part of Panton, again pushes this rock into the lake and it re-appears for the last time in Vermont at Adams' Ferry, in the northwest part of Panton. As before mentioned, it occurs in New York north of Split Rock.

While it is difficult to draw the line, in all cases, between the Utica slate and the Hudson River shales in the eastern range of slate, we have never felt any doubt as to the propriety of the name Utica for this band along the shore of the lake. Apart from its fossils, its thickness and extent are so small as to preclude the possibility of the presence of any newer rocks in connection with it.

The thickness of the Utica slate and Hudson River shales combined, has already been stated. We think that generally the thickness of the former, in Vermont, is about 100 feet, as stated by Prof. Adams. In Grand Isle the thickness must be greater, but we have used no means to ascertain how much greater it may be.

MINERAL CONTENTS.

The veins of milk-white and nearly transparent calcite have already been mentioned. So have the nodules of pyrites, which are extremely abundant in the North and South Hero Islands. Several mineral springs occur in this formation. The one at Alburgh is the best known. It is strongly impregnated with sulphureted hydrogen, and is visited by many invalids with beneficial results. It is in the east part of the town. We visited a similar spring, impregnated with the same reagent, near the church in South Hero, upon the land of Abel Phelps. Its quality is good, but we cannot compare it with the former spring, as we have not tested the qualities of the Alburgh water. It is probable that the sulphur arises from the decomposition of the nodular pyrites common in the slate; and that many similar springs of good quality may be found in this formation elsewhere.

FOSSILS.

Several species of fossils have been found in this rock in the limits of Vermont. They are *Graptolithus pristis* (Hisinger), *G. bicornis* (Hall), *Crania (?) filosa* (Hall), and *Triarthrus Beckii* (Green.)

Graptolithus pristis (Hisinger). Linear, straight, scarcely a line broad, compressed; rachis central, capillary; both sides with broad acute teeth.

This species occurs in small, short fragments, sometimes nearly two inches long. When the specimens are flattened, a central capillary axis is very perceptible, extending the entire length. In some specimens where the serrated portion is removed, this central axis is still preserved, extending beyond the other parts of the fossil. It expands gradually, from what appears to be the base upwards for some distance, but rarely exceeds a single line in width. The serrations are usually acute, but sometimes obtuse.

Fig. 223.

Graptolithus pristis.

Fig. 223 represents a fragment of the *Graptolithus pristis* from the Utica slate. This species has been found at several places on the shore of Lake Champlain in Bridport, along the same shore in some parts of Addison, at Snake Mountain, in Addison, at Adam's Ferry, in Panton, in Grand Isle, and at numerous localities upon North Hero; particularly upon its west side.

G. bicornis (Hall). Stipe linear, elongated, compressed, narrow, gradually widening from the base upwards; width one line or less; serrated on both sides; serratures slightly oblique; teeth about half the width of the stipe, obtuse at the extremities; axis capillary; base or radix bifurcate.

This species is easily identified by the obtuse teeth which are separated from each other by a narrow slit, and each one about half as wide as the entire width of the fossil; the slit or serrature extends about half way to the axis. The specimens all become gradually narrower towards the base, which presents two diverging forks; these are sometimes thickened or expanded, and in other cases very slender, the serræ often continuing beyond the divergence.

Fig. 224 represents a specimen of the *Graptolithus bicornis*, illustrating the two diverging forks at the smaller extremity. This species is associated with *G. pristis* in many of the localities already specified.

Fig. 224.

Graptolithus bicornis.

The *Crania (?) filosa* has already been described under Trenton limestone. It occurs in Utica slate in North Hero and the north part of Grand Isle.

Triarthrus (Green.) Shield or crest an elongated ellipse, with the posterior extremity narrower, than the anterior; crest comparatively smooth, with a single row of tubercles in the middle of the young, but often obsolete in the old; furrows of the cephalic shield parallel, straight, and in a line with those of the thorax; eyes none; axis wider than the lateral lobes; thoracic rings fourteen; rings of the pygidium, six in the middle lobe, and five in the lateral.

Triarthrus Beckii (Green.) General form an elongated ellipse, with the posterior extremity narrower and the sides often straight; buckler broadly semi-oval, the posterior angles rounded; glabella of equal width from base to front, rounded before, deeply trilobate on each side, with a prominent thoracic ring at the base; frontal lobe narrowed longitudinally; thorax with thirteen segments, those of the central lobe with a short spine or tubercle upon the back, those of the lateral lobes deeply grooved along the center; caudal shield with six or seven segments in the middle lobe, and five in the lateral lobes; posterior extremity obtuse.

In the Utica slate this trilobite has been found in North Hero and Grand Isle.

Fig. 235 represents an outline of the *Triarthrus Beckii*. This species is common to the Trenton limestone, Utica slate, and Hudson River slate.

Geological Position and Equivalency.

So much has been said of the order of the Champlain Group of silurian rocks, that it is unnecessary to enlarge upon its geological position here. The Snake Mountain section (Fig. 167) illustrates its entire connections. Under Trenton limestone there are two or three illustrations of its position in relation to that rock. They are Figs. 172 and 216.

HUDSON RIVER GROUP.

Until very recently geologists described under this name three different groups of rocks, entirely separated from one another geographically. The first, and one without doubt of Hudson River age, is the group of slates overlying conformably the Utica slate. The second group embraces the clay slates and sandstones of Franklin County, which pass into Canada. They are described in this Report as the Georgia slates. The third group embraces the clay slates and talcoid schists extending from Cornwall to Pownal, joining those rocks in New York described as Hudson River Group by the N. Y. Survey, and belonging to the same system as the second group. We describe in this connection only that group which is indisputably of this age, in a comparatively unaltered condition.

Lithological Characters.

The following are the chief varieties:

1. Large deposits of pure and impure limestone.
2. Clay Slate.
3. Calcareous Slate, interstratified with
4. Small beds of limestone, often sparry.
5. Silicious Slate.
6. Sandstones.

7. Brecciated Limestones.
8. Slate filled with veins of calcite, etc.

This group of rocks lying in contact with the Utica slate, from West Haven, (passing through the center) and the west part of Rutland and Addison Counties, passing at Shelburne, in Chittenden County, beneath Lake Champlain, and from Burlington to Canada, skirting the east side of Lake Champlain, may be easily divided into two distinct groups, which are distinguished from each other in our Geological Map of the State. The upper group consists almost exclusively of limestone, and the lower group of slates. The first variety embraces these *limestones*, and is of two kinds—a pure white or dove-colored limestone, and a dark, impure limestone, often dolomitic. The white variety is composed of the following substances:

Carbonate of lime, .	94.66
Carbonate of magnesia, .	.23
Alumina and iron, .	. 1.09
Silica, etc., . . .	2.39
Water and loss, . .	. 1.63
	100.00

A less pure variety is composed of

Carbonate of lime, .	. 70.00
Silica and Alumina, .	28.00
Iron and magnesia, .	. 2.00
	100.00

These specimens were from Rich's Quarry, in Swanton; and, particularly the first, give a proper idea of the composition of these beds of limestone. It is sometimes called dove-colored marble, or Swanton marble (not the black marble which is sawed at Swanton.) There is a continuous deposit of this limestone from Canada Line, in Highgate, to St. Albans Bay, gradually thinning out to the south, and appearing several times as insulated beds, south of this bay, but not south of Burlington, its place being supplied by the coarser variety. It is occasionally filled with veins of calcite, as at St. Albans Bay.

The other beds of limestone corresponding in position to those just described, are sometimes quite pure and nearly white, as in Rutland County, or so completely filled with veins of calcite, as to constitute *sparry limestone;* or the limestone is thick-bedded, silicious, gray or dark brown, and frequently destitute of any evidences of stratification, as is the variety north of Burlington; or finally, this limestone may be of a fine blue color resembling some of the blue limestones of the upper silurian. Under the *range and extent*, these beds will be described minutely.

Clay slate is the characteristic rock of this group. In Vermont, however, upon the western range, it is found chiefly in the south part. Between West Haven and Bridport it is the principal rock. North of Burlington, upon some of the Islands in Lake Champlain, and at St. Albans Point, it is also abundant. In the early part of our explorations we were troubled greatly by the impression, fostered by some geologists, that nothing but non-calcareous clay slates or shales ever constituted this formation. The color and hardness of clay slate varies from soft green and dark colored clay slate to the green and black ringing slates. There are many different shades of color in the clay slate, south of Bridport.

When this slate takes carbonate of lime into its composition without altering its black color, though at times the argillaceous odor has disappeared, we call it *calcareous slate.* In the greater part of the range this variety abounds, especially between Canada line and Bridport. Every grade, from pure clay slate to slaty limestone, is found. It is not improbable that the source of the dove-colored and silicious limestones in some places may be found in the melting up, as it were, of this calcareous rock. This struck us particularly at Snake Mt., where, within the distance of a mile, a great thickness of limestone destitute of stratification succeeds this calcareous slate, along the line of strike.

Prof. Thompson gives the following account of this variety in Chittenden County: "The black slate is generally contorted and crushed, and abounds in seams of white calcite, varying from a line to a foot in thickness. Still there are places where the spar has not been injected, and where the lamination has been disturbed. Cases of this kind may be seen on the east side of Pottier's Point, and at Appletree Point. But all this slate doubtless contains too much lime, and is too brittle to be used for any better purpose than making roads. This slate in many places, particularly where it is fragmentary, has its surface covered with a black glazing, giving it very much the appearance of anthracite. This may be seen near the meeting house in Charlotte, and at Lonerock Point, and it has led some to suppose that coal might be found in connection with it. But I believe very little, if any, money has been thrown away, in the vain search for coal in this county."

This variety is well developed at the northwest end of Snake Mountain, in Addison. We ascended the mountain in the bed of a small stream, which has exposed the slate almost every foot of the way. We found no seams that were not calcareous, and the amount of lime generally is quite large. This is an exposure that Prof. Emmons has examined with care. He regarded the slate as the uppermost member of the Taconic system, calling it the *black slate.* Our views upon this subject are given in full elsewhere.

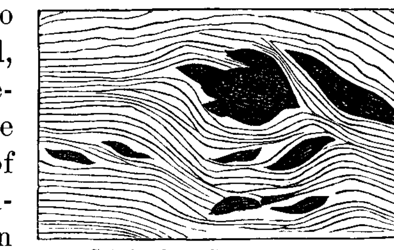
Often at this exposure thin beds of black limestone alternate with the slate, as in the Utica slate. This is common throughout the whole range. At Charlotte, at the foot of Glebe Hill, they are unusually numerous. At Stave Point in Colchester they have been burnt for quicklime, and answer very well for that purpose.

At St. Albans Point in clay slate, and upon Ram Island in St. Albans Bay, there are beds of silicious slate. This is a mass of flint or quartz rock of the same color as the slate. It is called black jasper by those that live in the vicinity, and this name gives a very good idea of its appearance. Upon Ram Island, parts of it are brecciated. We have traced this bed for about three miles, in a north and south direction.

It is unusual to find beds of sandstone interstratified with the shales and slates of this group, except in Rutland County. This sandstone is free from lime, and is durable and compact, like the sandstone of the red sandrock series that is found in the vicinity. The principal locality of it is in the northwest part of Benson, in a slate quarry. At the west end of the quarry there is a bed of sandstone six inches thick; at the east end there is another, fifteen feet thick (No. $\frac{6}{159}$). These beds are probably numerous in this region, lying about three-quarters of a mile west of the hill of red sandrock. We should expect to find small beds of sandstone in the vicinity of that rock.

Similar deposits, but more irregular, are found near the upper limits of these shales, beneath the sandstone, capping Snake Mountain. The slates there are bright and shining, traversed by irregular seams of calcite, as well as grit. Some of the layers near the sandstone are composed of a soft, green, slaty matter. At the junction there is an alternation, for a few feet, of the two rocks, as the commencement of the one which is to succeed, and thus the re-appearance of the mass beneath; and frequently large, irregular beds or portions of strata may be observed, as in Fig. 225. The black spots are masses of grit lying in the midst of the slate, insulated from the sandstone above. These irregular alternations continue for ten or fifteen feet, when the thick-bedded sandstone appears without any interruption. This figure was drawn by Prof. Emmons, for the Geological Report of the Second District, N. Y., page 280; where he says that these same irregular alternations may be traced for several miles along the junction of these two rocks.

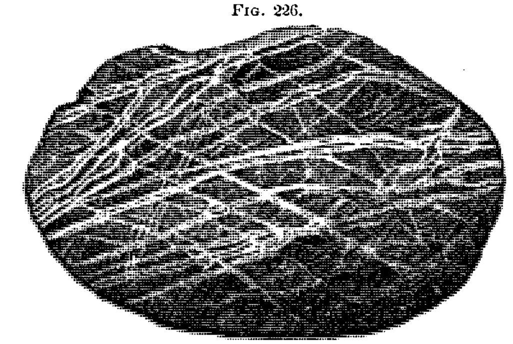
Fig. 225.



Grit in slate, Snake Mountain.

Sometimes brecciated limestones are found imbedded in the slates of this group, in which the fragments are derived of course from limestones of a previous age. In other slates, these fragments often contain the fossils of the group from which they were derived. We have found bowlders of this kind in Vermont, originally from Canada.

Fig. 226.



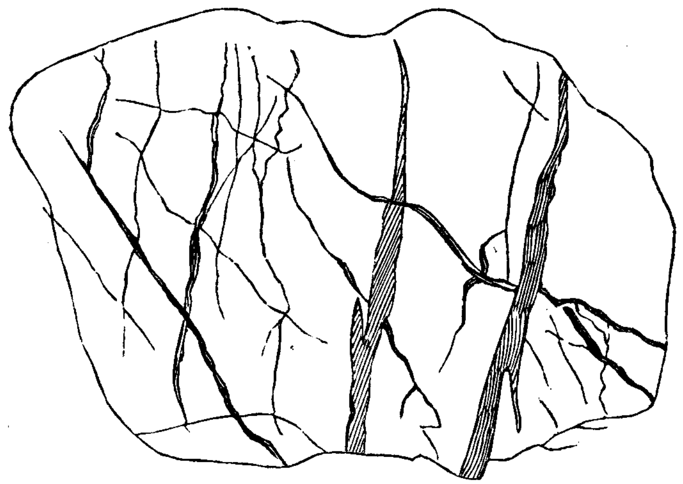
We have already referred to the veins of calcite which traverse the slates. So abundant are they in some places that they deserve to be noticed as a distinct variety. Along the shore of Lake Champlain, wherever these calcareous shales are found, they are often filled with these veins passing in every direction, crossing each other or passing along parallel to each other. Fig. 226 represents No. $\frac{10}{156}$ of the State Cabinet, which with Nos. $\frac{10}{161}$ to $\frac{10}{158}$ are from the north-east side of Pottier's Point, in Shelburne. The figure was taken from a pebble. The shore is lined with similar pebbles. But they are less interesting than the ledges, which for several rods are most beautifully covered with a network of dazzling white veins upon a black ground. Large specimens of them ought to be in every cabinet of geology in the country. For those who are studying the phenomena of veins this locality furnishes fine examples. Rarely in the most thoroughly metamorphic rocks have we ever seen veins equal to them in number, fineness, and complexity. It is mysterious how they could be formed, some of the veins being scarcely perceptible without a lens.

Fig. 227 represents veins of quartz in clay slate, in a small bowlder from Butler's Island. The bowlder is about four times larger than the figure, and is No. $\frac{12}{205}$ in the Cabinet. It is rather uncommon to find veins of quartz in this slate.

Besides these veins that intertwine with one another, there are veins in the rock that do not meet, being parallel, on the St. Albans coast. These veins appear in great abundance, and by their beauty rival the netted veins of Shelburne and elsewhere.

The sparry limestone at St. Albans Bay, and many other limestones further south, belong to this group. It is not confined to the so-called Taconic rocks.

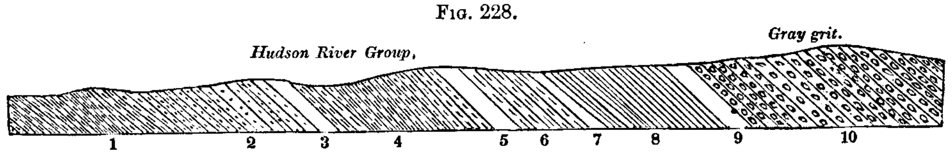
FIG. 227.



Veins in Slate, Butler's Island.

In the northern part of the State the beds of limestone in the Hudson River Group are sometimes dolomitic, or more often pure carbonate of lime. Fig. 228 shows the position of the various limestones and slates at Highgate Falls. It is altered from a wood cut in the Geology of the Second District of New York, p. 321.

FIG. 228.



Section at Highgate Falls.

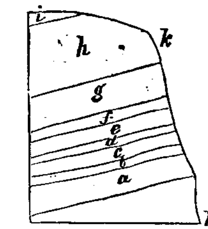
Explanation of Fig. 228.

1 Drab-colored, even-bedded layers.
2 Slate filled with imperfect concretions.
3 Drab-colored layers, similar to strata in the calciferous sandrock.
4 Drab-colored limestone, with a few fossils.
5 Even-bedded slate.
6 Slaty limestone.
7 Dove-colored limestone like the Swanton marble.
8 Slaty limestone.
9 Fragmentary limestone.
10 Masses of shale and grit, alternating regularly with each other, belonging to the Red Sandrock Series.

There is a considerable fall in the Missisco River at this locality, and a deep gorge has been worn through the rocks, so that their nature is distinctly seen. The section above is embraced in the space of fifty yards, and the height of the cliffs is generally more than fifty feet. The dove-colored limestones in general correspond lithologically to the belt of limestone a few miles west, as at Swanton Falls. It is a pure limestone traversed, or rather reticulated by veins of calcite. The stratification is very obscure, and the rock breaks naturally into irregular angular fragments.

Fig. 229 represents a section of the cliff upon the north side of Missisco River at Highgate Falls, a short distance below the principal fall. It was drawn by Prof. Thompson, whose notes are used in the explanation of the figure.

FIG. 229.



Section at Highgate Falls.

a Silicious limestone, four feet thick.
b Clay slate, one foot thick.
c Slaty limestone, two and a half feet thick.
d Silicious bed, with concretions, one foot thick.
e Black slate with iron pyrites, three feet thick.
f Stratum, one and a half feet thick.
g Contorted slaty limestone, six feet thick.
h Coarse silicious limestone with concretions, twelve feet thick.
i Alluvium.
k k represents the steep side of the cliff.

Many of the strata are filled with fine particles of iron pyrites, which appear to be uniformly disseminated through the mass.

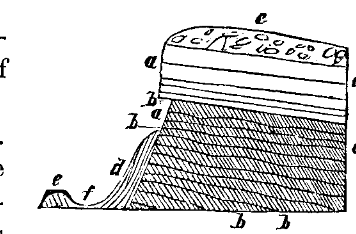
Divisional Planes.

Jointed planes occur in the beds of limestone most generally, though by no means wanting in the slates. Inadvertently we have no observations to record, but the jointed structure of the limestone at Snake Mountain is as vivid in our memory, as it was to our vision at the time of our visit. They cross the range nearly at right angles, being vertical planes of separation. We have numerous observations upon the position of the cleavage planes of the slates in the following table:

Locality.	*Strike.*	*Dip of Cleavage.*	*Dip of the Strata.*	*Authority.*
Bridport, east of village,		43° E. to 20° E.,		C. H. H.
Addison, Cobble Hill,	N. 10° E.,	75° E.,		C. H. H. and A. D. H.
Addison, Cobble Hill,	N. 10° E.,	60° E.,		C. H. H. and A. D. H.
Bridport, northeast corner,	N. 80° E.,	50° S.E.,		E. H., etc.
North Ferrisburgh,		75° E.,	15° E.,	C. H. H.
Shelburne, west of village,		68° E.,	15°–20° E.,	C. H. H.
Shelburne, Pottier's Point,		42° E.,		C. H. H.
Milton, west shore,	N. 53° E.,	30° S.E.,	10°–15° S.E.,	C. H. H.
Milton, northwest corner,	N. 53° E.,	35° S.E.,	12° S.E.,	C. H. H.
St. Albans Point,		30° S.E.,	5° S.E.,	C. H. H.
Lonerock Point,		45° E.,	10° E.,	C. H. H.
Welden's Island,	N. 40° E.,	23° E. and 70° E.,	6° E.,	C. H. H.
Potter's Island,	N. 40° E.,	23° E. and 70° E.,	6° E.,	C. H. H.

Thus the angles of inclination of the cleavage planes and of the strata differ from each other greatly—from 15° to 60°. We give, in Fig. 230, a section of Lonerock Point, illustrating the difference between the cleavage planes and the strata.

FIG. 230.



Lonerock Point.

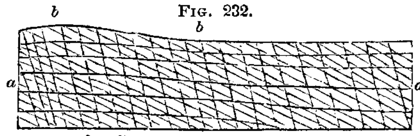
It is owing to the compactness of the redrock that the Point remains, especially in the form of a long bluff. The red rock seems almost destitute of any marks of stratification. Its position, however, is unequivocal.

Its dip is about 5° or 6° E., while the slate beneath dips about 10° E. The cleavage planes dip about 50° E. In the figure, *a a* represent the planes of stratification, *b b* those of cleavage. Above the limestone, *c* represents fragments of rock and soil. Upon the edges of the strata, *d* represents fragments of strata and limestone that have been separated from the rock in place; and it was in these fragments that Prof. Thompson discovered fossils. *e* represents a large block of the magnesian limestone that has been separated from the cliff above. *f* represents the level of Lake Champlain. The height of the cliff is about fifty feet; the slate varying from ten to thirty feet in thickness.

Many observers have supposed that these cleavage planes were the true planes of deposition, and that there is therefore very great unconformability between the two rocks. The planes of stratification are certainly indistinct; but they show themselves most decidedly to the observer, as he sails past the Point at a little distance from it. We are happy to be informed by Sir W. E. Logan that he has examined this locality, and has arrived at the same conclusion with ourselves in respect to the dip.

From our note books, we find that upon Welden's Island, and upon Potter's Island, in the north part of Lake Champlain, there are, in addition to the strata, two sets of cleavage planes. The strata dip six degrees east, the cleavage planes dip 20° E. and 73° E. We have attempted to represent these three planes upon Fig. 232: *a, a,* represent the strata, which are a little more uneven in the drawing than in nature, in order to impress the distinction; *b, b, b, b,* represent the two sets of cleavage planes. We have separated the lines to indicate cleavage more than usual in our representations, that their positions may be clearly appreciated.

Fig. 232.



b Section at Potter's Island. b

DIP AND STRIKE OF THE STRATA.

Locality.	*Strike.*	*Dip.*	*Observer.*
West Haven, post-office,	N. 10° E.,	22° E.,	E. H., jr. C. H. H. and A. D. H.
West Haven, west of post-office,	N. 30° E.,	50° E.,	C. H. H.
West Haven, east of post-office,	N. 10° E.,	40° E.,	E. H., jr. C. H. H. and A. D. H.
Benson, south part,	N. 20° E.,	35° E.,	C. B. A.
Benson, northerly part,	N. 20° W.,	33° E.,	C. B. A.
Benson, north part,	N. 26° E.,	53° E.,	C. H. H.
Benson, north line,		35° E.,	C. H. H.
Benson, north part,	N. and S.,	50° E.,	C. B. A.
Orwell, village,	About N. and S.,	10°–12° E.,	C. H. H.
Orwell, south of do.,	N. 5° E.,	45°–60° E.,	A. D. H.
Orwell, Asa Young's,	N. and S.,	25° E.,	C. H. H.
Orwell, east part,		Horizontal,	C. H. H.
Orwell, east part,		50° E.,	C. H. H.
Shoreham, west of village,	N. and S.,	45° E.,	C. H. H.
Shoreham, north part,		85° E.,	A. D. H. and C. H. H.
Bridport, east of village,		20° E.,	C. H. H.
Addison, Cobble Hill,	N. 20° E.		A. D. H. and C. H. H.
Addison, Cobble Hill,	N. 10° E.,		A. D. H. and C. H. H.
Bridport, northeast corner,	N. 80° E.,		E. H., etc.
Bridport, northeast corner,	N. 25° E.,		E. H., etc.
Weybridge, Wright's Monument,		Dip east,	C. H. H.
Addison, northwest foot of Snake Mt.,	N. 20° E.,	30° E.,	A. D. H.
Addison, northwest corner of Snake Mt.,		10°–20° E.,	E. H.
Addison, Snake Mountain,		40° E.,	C. B. A.
North Ferrisburgh, east part,		15° E.,	C. H. H.
Charlotte, northeast of village,		10° E.,	C. H. H.
Charlotte, Mutton Hill,	N. 45° W.,	25°–70° E.,	A. D. H. and C. H. H.
Shelburne, west of village,		15°–20° E.,	C. H. H.
Shelburne, west part,	N. and S.,	15° E.,	C. H. H.
Shelburne, Pottier's Point, west side,		Dip east,	C. H. H.
Shelburne, do., east side,		10°–60° E.,	C. H. H.
Shelburne, Pottier's Point,	N. 10° E.,	30°E.,	C. B. A.
Shelburne, Pottier's Point,	N. 80° W.,	40° N.,	C. B. A.
Milton, Lake shore,		10°–15° E.,	C. H. H.

Milton, northwest corner,	N. 53° E.,	12° S.E.,	C. H. H.
Georgia, Lake shore,		20° E.,	C. H. H.
Ram Island,	N. 45° E.,	30° S.E., (?)	C. H. H.
Welden's Island,	N. 40° E.,	6° E.,	C. H. H.
Potter's Island,	N. 40° E.,	6° E.,	C. H. H.
Butler's Island,		60° E.,	C. H. H.
Knight's Island,		30°–50° N.E.,	C. H. H.
St. Alban's Point,		5° E.,	C. H. H.
St. Alban's Bay,	N. 10° E.,	30°–50° E.,	E. H., etc.
St. Albans, northwest part,		About 25° E.,	C. H. H.
Colchester, west part,	N. and S.	70° E.,	C. B. A.
Swanton, south part of Hog Island,	N. 35° E.,	46° W.,	C. B. A.
Swanton Falls,	N. 50° E.,	75° E.,	C. H. H.
Swanton, west of Falls,	N. 10° W.,	70° E.,	C. H. H.

This table embraces all the slates of this group. The mean strike of all the observations is N. 23°E.— Deducting from this 10°, the allowance for the variation of the magnetic needle, and the mean strike then will be N. 13° E. The strike of the formation as projected on the map is N. 7° E. The difference between them is six degrees. There is perhaps more reason to expect discrepancy here than in the other groups, because the observations were less accurate, and there are more local disturbances.

The preceding table gives the position of the strata of shales and slates. The limestone beds were so uniformly in the upper part of the formation, that we have thought it best to give their position separately.

Localty.	*Strike.*	*Dip.*	*Observer.*
West Haven, east part,	N. 30° E.,	42° E.,	E. H., jr.
Orwell, village,		5° E.,	C. H. H.
Orwell, south of do.,	N. 60° E.,	30° S.E.,	C. H. H.
Shoreham, north part,	N. 10° E.,	15° E.,	C. H. H.
Addison, Cobble Hill,	N. 50° E.,	55° S.E.,	C. H. H.
Addison, Cobble Hill,	N. 20° E.,	12° E.,	C. H. H. and A. D. H.
Addison, Snake Mountain,	N. and S.,	30° E.,	C. H. H. and A. D. H.
Addison, top of do.,		5° E.,	E. H., etc.
Milton, northwest corner,	East of north,	About 10° E.,	C. H. H.
St. Alban's Bay,	N. 10° E.,	30°–50° E.,	E. H., etc.
Swanton, Rich's quarry,	N. 45° E.,	25° S.E.,	C. H. H.
Georgia,	N. 30° E.,	23° E.,	Z. T.
Highgate, middle part,		Dip east,	C. H. H.
Highgate, north of Springs,		62° W.,	E. H. and C. H. H.
Highgate, do.,		36° E.,	C. H. H.
Highgate, do.,	N. 65° E.,	30° S.E.,	C. H. H.
Highgate, east of Springs,		20° E.,	C. H. H.

These limestones all dip to the east.

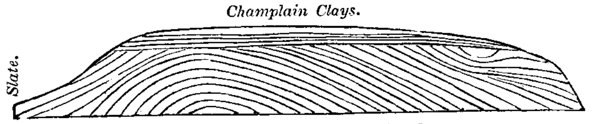
The general dip of the slates is to the east. Variations to the north and northeast are caused by a corresponding change in the direction of the formation. Only one westerly dip is recorded,— that is on Hog Island in Swanton. There is an anticlinal in the slate in this town, caused by the folding of the strata.— It disappears to the south, unless it be an inverted anticlinal,— but is exhibited better to the north, in Canada. Upon the same anticlinal Utica slate was found in North Hero, dipping to the west. This is the great anticlinal separating the eastern and western basins of Palæozoic rocks from each other in Canada.

Upon the islands in Lake Champlain there are many small disturbances. It is generally the case that the outer cliffs dip much more than the interior parts of the islands. Knight's Island is an example. The cliffs on the west side of the island dip 50° E., but in the south side, and not far from the highly inclined strata, the dip is 30° E. There seems to have been some force, perhaps from causes now operating, like small icebergs, or the freezing of water, that tends to throw up the edges of the islands only, and particularly the western edges.

Our notes also state that upon these eastern islands there are numerous small folds in the strata Single layers, a few inches thick, will form a loop, and the loop itself be interstratified with the other layers; in other words, they are miniature inverted anticlinals, so numerous as to arrest the attention, and that not merely upon a single island. They are not far from the strike of the Highgate anticlinal. We do not suppose that their looped strata necessarily imply more than that there has been a considerable pressure exerted upon these strata, and that force acted probably at the same time that the neighboring anticlinal was folded up.

Fig. 233.

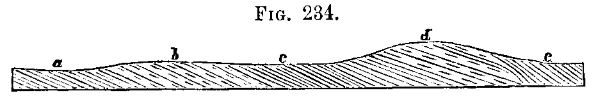
Champlain Clays.



Section of Welden's Island.

Fig. 233 shows the position of the strata upon Welden's Island, near St. Albans. The eastern side of the island, where the sketch was taken, is about twenty five feet high. The cliff is found upon every side except the north, where it slopes gradually to the level of the lake, the slope being covered by Champlain clay. Numerous large bowlders of Laurentian rocks from Canada are strewn at the base of the cliffs. The section is about half a mile in length.

Fig. 234.



Section at Rich's Quarry, Swanton.

Explanation of Fig. 234.

a Hudson River shales.
b Swanton marble, or dove-colored limestone, out of which the stone quarried at Rich's quarry is obtained.
c Clay slate, run east of Rich's quarry, near the Vt. and Canada Railroad. Supposed to be of the Hudson R. Group.
d Variegated dolomites of the Red Sandrock Series.
e Georgia slate.

Fig. 234 in connection with Figs. 228, 229 and the Geological Map, Plate I, illustrate a development of clay slates in the northern part of the Hudson River Group, which has not been observed south of St. Albans, namely:—there is quite a thickness of clay slates, *c*, in Fig. 234, in the upper part of the group; between the upper limestone, *b*, which is elsewhere at the top of the series, and the red sandrock series, *d*. Prof. Emmons regards this slate, *c*, as of the same age with the Georgia slate, *e*, and supposes that the red sandrock, *d*, is not interstratified with the slates, but rests upon them unconformably. And he regards both the slates as Taconic slate.

There is a question of great importance concerning the stratigraphical relations of this upper band of clay slates to the red sandrock series which we cannot answer satisfactorily to ourselves, without further investigation. With this question is also involved the age of the slates, whether they are older or newer than the red sandrock series, and whether the slates west of the red sandrock are the same with the Georgia slates east of the red sandrock. The two geologists who have examined the positions of these rocks in northern Vermont or Canada—Sir W. E. Logan and Prof. Emmons—agree in regarding the red sandrock series as of lower silurian age (near the calciferous sandrock), and also agree in considering the Georgia slate as older than the red sandrock. Logan calls all the slates west of the red sandrock Hudson River slates, while Emmons regards a part of them—those nearest the red sandrock—as Taconic. Consequently they differ in their

views of the stratigraphical position of the shales west of the red sandrock, and the red sandrock itself. Logan supposes (see his letter to Barrnade in another part of this Report) that the red sandrock has been elevated independently of the Hudson River slates, and was then folded over upon the latter, so that now an older rock rests upon a newer rock *conformably*. Emmons supposes that if there has been any elevation, the slates have been brought up with the red sandrock, and that the relations of the two to each other have not been disturbed by any foldings or inversions of the strata. The red sandrock he supposes to rest unconformably upon these slates.

To illustrate these views, Prof. Emmons has given two figures in his *American Geology, Part II*, pages 81, 82, representing the relative positions of the red sandrock and slates.—The locality of these sections is very near that of Figs. 228 and 229. He says: "At Highgate, in Vermont, the Missisco passes through a gorge just below the bridge. The calciferous sandstone [red sandstone] lines its banks on both sides, but some distance below, the junction of the calciferous sandstone is entirely concealed, even at rather low stages of water; and, from the irregularities of the slate which jut up, it appears that the limestone might form a part of the group, by plunging down between the beds of slate.—On visiting this locality at a very low stage of water, I found that the calciferous rested in an irregular trough in the slate and also upon its upturned edges. This fact explained all the obscurities which had formerly raised doubts in my mind respecting the relations of this rock to the slate; and, besides, the folia of the slate are bent at the junction of the two rocks, which in this case I attribute to the force which has been communicated to the rocks, although it often occurs that folia of slate are puckered at the junction of a seam of calc spar with the slate."

In another part of this gorge, Prof. Emmons discovered an anticlinal in the slate, and the grit rock is represented as lying unconformably upon the slates upon both sides of the axis. We did not discover such a position of things in our hasty examination of the spot, though we did discover an unconformability of the two rocks. There is certainly a want of conformity between the slates and the grits, both at Highgate Falls and about two miles further north, where Fig. 247 was drawn.

The question to be decided now is, whether the want of conformity between these two rocks in Highgate is found elsewhere,—whether it is not a local affair. Even if it be ultimately decided that these two rocks are unconformable to each other, the decision will amount to simply this: the grits overlie the slates unconformably. It does not decide whether the slates are of the Hudson River age, or of the age of the Taconic slates, or of the Georgia slates. There is no reason in the nature of things why the red sandrock should not overlie the Hudson River Group unconformably.

We think that a careful investigation of these rocks would show conclusively, from the true or inverted position of rain marks, ripple marks, and shrinkage cracks, whether any of them are inverted or not. We shall wait for such investigation before we give an opinion on the subject.

Further remarks upon this subject will be found in connection with the description of Fig. 247.

Range, Extent and Thickness.

We will speak first of the dove-colored variety of the limestone portion of the group. We take the following remarks concerning it, from Prof. Thompson's notes:

"This rock was first observed [in Chittenden county], beginning at the south in Charlotte, just east of the summit of the high ridge extending south from Globe Hill. Its thickness here is only a few feet, and it is seen only a short distance north and south. It next appears on the west side of Lonerock Point. Lying in the form of a wedge between the red sandrock and black slate, rapidly increasing in thickness towards the north, attaining to 20 or 30 feet before it becomes concealed at Eagle Bay. It appears again in Colchester on the southeast side of Mallet's Head: also at Stave Point on the north side of the outlet of Mallet's Bay, where there is a kiln for burning it into quicklime. In all these places it lies under, and in contact with the red sandrock. From Milton through Georgia to St. Albans Bay, it is abundantly developed at a short distance from the lake shore, being most of the way several rods in width, at the surface of the ground. In Swanton it appears again at several places; and at one locality, half a mile southeast from Swanton Falls, it has been quarried for marble. The width of the exposure here of nearly naked rock is about 25 rods, and it extends half a mile north and south, only very slight signs of stratification are any where to be found in it. It is cracked and checked in various directions, and there are some appearances of planes of deposit dipping East about 45°.

"This rock shows itself through most of the township of Highgate, and extends into Canada."

There is a large amount of this limestone in Highgate. There is no slate between it and the Trenton limestone. It is from one to two miles in width, narrowing at the south part of the town. North of Saxe's mill it appears in large, white bosses arising out of the lowland. Near Church's house, nearly east from Franklin house, the limestone is brecciated, and among the fragments the Trenton limestone is clearly discernible. At Highgate Falls this limestone is interstratified with various kinds of slate, as is seen in Fig. 256, and the great mass of it extends quite near to the Falls. East of Swanton Falls it is very wide, and is of fine quality, insomuch that it has been sawed for marble, but with poor success. Much of it is traversed by numerous small reticulated veins of calcite, and it breaks into irregular angular fragments, like the limestone in Colchester.

In passing south to the coarser limestones, we first find it northwest of Burlington, in the vicinity of Lone Rock Point. We next saw it in Ferrisburgh, in occasional suddenly expanding beds; particularly east of Vergennes, and in sight of the village. It much resembles serpentine at a distance. We crossed the range next northeast of Snake Mountain, where the western border of the Red Rock, the east line of Addison and the carriage road from Addison to New Haven, all meet at Otter Creek. At about the middle of the highest part of Snake Mountain on the west side among the debris, this ugly rock takes another start; and we can trace it a great distance. It appears through the whole of the east part of Bridport. A few obscure fossils, probably of the genus Euomphalus, appear in it in the northwest part of the town. It is in a ledge of this rock, near Mr. Gale's house, near the east line of Bridport, that metamorphosis first fairly takes hold. East of it, as far as the quartz rock, nothing but white limestone is found; west of this ledge fossils occur abundantly in the unaltered Trenton limestone.

As the red sandrock thins out in Bridport, it is difficult to separate this limestone from the Eolian limestones east of it, especially as all of them are more or less metamorphic. But we feel assured that fifty or a hundred feet of the lowest of limestones are of this group, lying directly upon slates. We will particularize the localities of what we refer to this group:

Southwest of G. Gale's house, on the direct road to Bridport, near Mr. Hamilton's house.

On the road to Shoreham, near O. Kitchel's house. The rock here is metamorphosed into beautiful white limestone, which is manufactured into excellent lime.

A short distance south of the preceding locality, there is a blue tough limestone of the same group; and a similar rock occurs at intervals along both roads, running south towards Shoreham; the one passing A. H. Rice's house; the other by J. Barbour's — both in Bridport.

Sparry limestone, in the north part of Shoreham, at a saw mill, west of A. Birchard's house.

At Shoreham village.

Near the south line of Shoreham, on the direct road to Orwell. Most of the ledges on this road are covered by Champlain clay; the others are metamorphic limestone.

There are several exposures of a limestone in Orwell Center, that we are inclined to refer to this rock. It is calciferous, and is nearly horizontal. East of it a few rods, there is slate, interstratified with limestone, holding fossils. Prof. Emmons considers this limestone at Orwell village, the calciferous sandrock.

A bed of limestone in the south part of Orwell, a little west of the middle of the south line.

A bed of bluish limestone, half a mile east of Benson Center.

Another one in this vicinity is mentioned by Prof. Adams, and stated to contain fossils. We have scarcely looked at this town, but doubt not that other beds of limestone are common in the slate.

In West Haven, Section VI. passes through at least three beds of this limestone, one of which is just west of the Post Office, where the rock is compact, of a bluish-white color, and is traversed by peculiar veins of calcite, appearing much like the segregated veins of limestone that have never been melted. Another a mile east of the Post Office.

The third bed is near Hubbardton River, and is more than a mile wide.

These alternations of limestone and slate have been very puzzling to us, and we do not feel fully satisfied that they all belong to this belt of limestone. We feel the least confidence in the two last mentioned. But yet we do not see why they should not be regarded as of nearly the same age, since it is a well known condition of things, that where two rocks approach each other, the different beds alternate. These limestones are represented on the map as distinct from the shales.

The slates of this group universally lie to the west of the limestones just described. Commencing at West Haven, there is a continuous belt, extending from Poultney River east of the Trenton limestone and Utica slate (wherever the latter exists), north through Benson. We crossed it at Benson Center, and found tolerably good quarries of roofing slate in the northwest part of the town. A mile west of Martin's Pond, on the north line of the town, and east of H. O. Stacy's house, may perhaps be the eastern border of this belt: for there we find an exposure of a red sandstone, which we have hesitatingly referred to the red sandstone series. Several layers of sandstone are also found in the clay slate to the west of Stacy's.

The slate thins out rapidly as we approach Orwell. It passes west of the village in such an inferior development as to be recognized with difficulty. It thickens, however, to the northward, but the distinct argillaceous character has become greatly obscured by the incorporation of more or less of the carbonate of lime into its composition. West of Shoreham village, there are ledges extending over a width of at least half a mile, that are comparatively free from lime. The two varieties interstratified with each other pass to Bridport, and show themselves a little east of the village—and there are developed along a direct line to Snake Mountain. Because of the great imperfection of all maps, one might be led to suppose that the amount of this slate at Snake Mountain is unusually small, because it narrows to this point so greatly. But it is of uniform thickness from Shoreham to Charlotte, and the narrower the surface that is covered, the steeper is the hill upon which it crops out. At Snake Mountain, for example, the whole surface of the Hudson River slate is very steep, insomuch that it can hardly be used for pasturage. Fig. 167 illustrates this position.

The range curves eastward from this mountain, and shows itself where the town line of Addison intersects Otter Creek. It is found all along the steep, west side of the range of hills running through Waltham. As soon as it enters Ferrisburgh it is concealed beneath the soil, as indeed are all the adjacent rocks, as they cross the valley in which the R. and B. R. R. passes to New Haven. In Ferrisburgh it appears on the west side of Marsh Hill, Shell House Mountain, and Mount Fuller. At the mills in the northeast corner of the town it is very conspicuous. In Charlotte the slate appears on the west side of the same range of hills, viz; Mount Philo, Pease Hill, and Mutton Hill. To the north it spreads out over more of the surface, covering the whole of Pottier's Point in Shelburne.

Perhaps it may include Rock Dunder, though that rock is described under Utica slate, there being no fossils found in it to determine its age. Between Lonerock and Appletree Points in Burlington, it re-appears after a bath in the lake, and proceeds north across Colchester Point. To the north it occupies the bed of the lake between the Hero Islands and the coast of Franklin County. The edges of Milton and Georgia are barely touched by it the whole distance. The islands are made of this slate, whenever they are not composed of clay or sand. They are Gull Island, Fish Bladder Island, Savage's Island (where explorations have been made for roofing slate), Welden's Island, Potter's Island, Ram Island, and the other small island in St. Albans Bay, Wood's Island, Knight's Island, Butler's Island, Diadama's Island, Hen Island, and Hog Island in Swanton, most of which is properly a delta of Missisco River.

Upon the main land in Franklin Co., beginning at St. Albans, this slate continues to increase in width as far as Swanton. It is the widest at Rich's quarry, in the south part of the town. It is well shown upon the banks of Missisco River at Swanton Falls, and at Mr. Clark's house a mile or so west of the village. In this vicinity it divides, the greater part passing to the west of the Trenton limestone at Highgate Springs. East of the springs there is a wide plain upon which no rock is seen, which is the place for the

slate to appear if it has not entirely thinned out before reaching that point of latitude.—Between the springs and Swanton Falls, the rocks in place are so much obscured by the overlying alluvium, that it is difficult to know what kind of ledges occur beneath.

But while it seems strange that so little of the Hudson River slate appears between Swanton Falls and the Canada line, we can find reason for its disappearance in the fact that there has been an elevation of an older rock at Highgate Springs, which also must have elevated the slates. Because denudation has been great at this place, the easily decomposable slates have mostly disappeared, leaving the underlying rock instead. If we suppose, as seems most probable, that the limestone beneath has been elevated above its normal position, it is probable that the reason why the slates do not appear over them upon the east side, where nothing but the dove-colored limestone is found, is that the slate is too deeply seated in the earth to be seen. Its whole thickness may be present, yet be unseen. It is a region of disturbance; and the slates may easily have sunk so low that only the superior limestones appear.

The thickness of the Hudson River Group upon Prof. Adams' section at Snake Mountain is 930 feet. Deduct 70 feet for the limestone, and there remain 860 feet thickness of slates and shales. The limestone we should estimate at more than a hundred feet in thickness in the north part of Franklin County. We have paid scarcely any attention during the progress of the survey to the measuring of the thickness of the rocks; more particularly because most of the formations in the State are so thick that neither geologists nor other people would believe us if we stated the results in the Report.

We have observed no minerals except calcite, and that in great abundance in veins, in this formation.

Geological Position and Equivalency.

The rank of this group as the highest member of the lower silurian is well established by Palæontologists. The Snake Mountain and other sections, already presented, prove the same thing.

There is an item of interest under this head respecting the relative position of some of the different members of the group itself—or between the lower slates, and the upper belt of pure white and dove-colored or less pure varieties of limestone and dolomite. The most satisfactory sections are those that place these limestones at the top of the slates, between them and the sandstones above. But some sections do not correspond to this idea; especially those at Rich's quarry in Swanton and in Highgate. There seems to be a small thickness of slates intervening. This fact, however, may be regarded as settled—that these limestones occur only very near, or at the top of the group. It is a curious fact also that often they form a wedge-shaped mass between the slate and sandstone. Another fact is, that when the sandstone is replaced by dolomite, the two formations pass into each other insensibly.

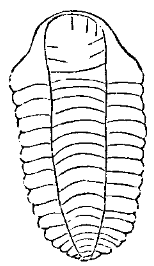
ORGANIC REMAINS OF THE HUDSON RIVER GROUP.

We have made scarcely any effort to obtain fossils from the Hudson River Group, and consequently our knowledge of the life of this period in Vermont is exceedingly meager. We have seen in this rock undescribed species of *Fucoids*, several *Graptolites*, a species of *Stromatopora* (?), *Chætetes*, *Lycoperdon* (Hall), an undescribed species of *Euomphalus*, and the *Triarthrus Beckii* (Green.)

The graptolites seem to be allied to the species found in Utica slate, and have been found at Appletree Point, and Lonerock Point in Burlington. The Stromatopora (?) was found in the Hudson River limestone in Orwell. It is a genus of coral, which has never been found elsewhere below the Niagara or Clinton groups of the upper silurian. The specimens are obscure, yet seem to be related to Stromatopora. Much better specimens of the same fossil were found in the Eolian limestone, which is very near the Orwell, limestone.

In the east part of Bridport, in a limestone which we have referred to the Hudson River Group, chiefly from its nearness to the red sandrock, we were shown specimens of the Chætetes lycoperdon, by Rev. Augustus Wing, of Stockbridge. The same gentleman called our attention to numerous fossil shells in undisputable Hudson River limestone, which belong to the genus Euomphalus. These remains are all imperfect, but they are very numerous in certain localities, and probably a little research will bring to light specimens of such perfection, that their specific characters may be ascertained. They have been found at Benson, Orwell (particularly near the village), east part of Bridport, Snake Mountain, and upon the town line between Monkton and Ferrisburgh, upon the west side of Mount Fuller.

Fig. 235..



Triarthrus Beckii.

The *Triarthrus Beckii* has been already described under Utica slate. It is poorly represented in Fig. 235. It has been found at Snake Mountain, and upon Appletree and Lonerock Points in Burlington, in the slates underlying the red sandrock series. Inasmuch as Prof. Emmons supposes this trilobite to be altogether different from the *Triarthrus Beckii* of the Hudson River Groups, we deem it proper to state his views in regard to it, as expressed by himself in his work on *American Geology*, Vol. I, Part II, pages 115, 116.

"Atops Trilineatus, *Calymene Beckii* (Hall.) Crust granulated, cephalic shield semicircular, with its anterior and lateral edges turned upwards, posterior angles rounded, facial suture beginning at the outer angle of the cephalic shield, and runs nearly parallel with the anterior margin to the middle lobe, when it turns at a right angle and runs parallel with that lobe; eyes undistinguishable, body composed of seventeen or eighteen rings, narrowing very gradually to the caudal extremity; pygidium a flat expansion of the crest and is provided with a single ring; axis narrower than the lateral lobe, rings seventeen, each of which is separated by a groove about as wide as the rings. Axis armed by a row of short spines; lateral lobes provided with a row of tubercles or prominences along the median line; margins of the rib groove run parallel as far as the tubercle, when they diverge; tubercles become obsolete towards the tail; caudal shield very small and provided with one, or at most two rings.

"This fossil has been confounded by Mr. Hall with the *Triarthrus Beckii* (Green), *Calymene Beckii.* He has been misled by the row of short spines along the middle lobe or axis, which it is well known exist in that species. It differs, however, from the *Triarthrus* in every other character; in the number of abdominal and caudal rings, the proportions of the subdivisions of the head, the granulations of the integuments and the row of tubercules along the lateral lobes. So palpably different were the heads of the *Atops* and *Triarthrus*, that a committee of the American Association decided they were different from the heads alone; and since this decision was made the specimen figured has been found, which sets the question at rest."

GEOLOGICAL CHARACTER OF THE ISLANDS, POINTS AND HEADLANDS OF LAKE CHAMPLAIN.

We introduce here the geological character of the different islands, points, and headlands, of Lake Champlain, in a separate table. As most of these points are lower silurian, this is the proper place to present it. It will be of service to those that wish to follow in the path we have traced among the interesting localities of fossils, etc., upon the lake. Details respecting the position of the rocks and interesting facts, will be found under the several formations. These observations were taken from the notes of all the different Principals and Assistants. To give symmetry to this list, the geological character of points of the shore belonging to New York are given, many of which were examined for this purpose. We commence at the south end of the lake and proceed northwards.

Whitehall Bay,	Potsdam sandstone.
Whitehall, steamboat landing,	Potsdam sandstone.
Whitehall, north coast,	Alluvial marsh.
Whilehall, along Poultney river,	Calciferous sandrock.
West Haven, along Poultney river,	Champlain clays.
West Haven, south point,	Potsdam sandstone.
West Haven, Chapman's landing,	Calciferous sandrock.
Dresden, N. Y., the following order:	A marsh;
	Bluffs of calciferous sandstone;
	Pebbly beach;
	Potsdam sandstone;
	Gneiss.
Kenyon Bay, N. Y.,	Clay and Potsdam sandstone.
Between Kenyon Bay and Mt. Defiance,	Champlain clay.
Benson, Kenyon Bay,	Calciferous sandstone.
Benson Landing,	Calciferous sandrock.
Benson, Stony Point,	Calciferous sandrock.
Orwell, Chipman's Landing,	Shales of calciferous sandrock.
Orwell, southwest coast,	Calciferous sandrock.
Orwell, Mt. Independence, west side,	Potsdam sandstone, but mostly calciferous elsewhere.
Putnam, N. Y., south part,	Champlain clay.
Putnam, N. Y.,	Gneiss and a little Potsdam sandstone.
Ticonderoga, N. Y.,	Calciferous sandrock.
Larrabee's Point, south part,	Shales of calciferous sandrock, Chazy limestone, and Isle La Motte marble.
Larrabee's Point, north part,	Trenton limestone.
Crown Point, N. Y.,	Chazy and Trenton limestones.
Jones' Wharf, Shoreham,	Slaty Trenton limestone.
North of do.,	Trenton limestone.
Bridport, S. W. coast,	Utica slate.
Bridport, Frost's Landing,	Trenton limestone.
Bridport, Jones' Wharf,	Utica slate.
Bridport, northwest part,	Chazy limestone.
Addison, Chimney Point,	Chazy limestone.
Addison, north of do.,	Trenton limestone.
Addison, Elm Pt., Queen Pt., and Potash Bay,	Utica slate.
Addison, Elm Point,	Quartz bowlder, 33 by 12 by 10 feet.
Port Henry, N. Y.,	Calciferous sandrock and Potsdam sandstone.
Port Henry, N. Y., north of,	Gneiss and iron ore.
Port Henry, N. Y., Cedar Point,	Potsdam sandstone.
Mud Island,	Utica slate and Champlain clay.
Ferris Island,	Utica slate.
Panton, Arnold's Bay,	Utica slate.
Panton, Adams' Bay,	Utica slate and Chazy limestone.
Order from southwest corner of Wesport, N. Y., to Split Rock:	Clay and Potsdam sandstone;
	Clay and calciferous sandrock;
	Clay and gneiss;
	Reddish porphyry.
Essex, N. Y.,	Utica slate and Trenton limestone.

Button Bay, south part,	Utica slate and Trenton limestone.
Button Island,	Fine locality of fossil corals, upper part of C. limestone.
Scotch Bonnet,	Chazy limestone.
Basin Harbor,	Chazy limestone.
Diamond Island,	Chazy limestone.
Ferrisburgh, northwest shore,	Chazy limestone.
Charlotte, Thompson's Point,	Calciferous sandrock on extreme point, rest Chazy limestone.
Charlotte, Birch Island,	Chazy limestone with a dike of porphyry.
Charlotte, Butterfield's Island,	Chazy limestone.
Spicer's Island,	Chazy limestone.
Great Bluff Point,	Trenton limestone.
McNeil's Point,	Trenton limestone.
Sloop Island,	Chazy limestone.
Smith's Point and Holme's Point,	Utica slate.
Dike Point, Shelburne,	Dikes of trachyte, porphyry and trap, with Utica slate.
Shelburne, Pottier's Point,	Utica and Hudson River slates.
Shelburne, Nash's Point,	Utica slate.
Potter's Island,	Utica, etc., slates.
Rock Dunder,	Utica slate.
Juniper Island,	Utica slate.
Willsborough, N. Y.,	" Slate."
Willsborough, N. Y.,	Hypersthene rock and Potsdam sandstone.
Port Kent, N. Y.,	Potsdam sandstone and Champlain clay.
Four Brothers,	Trenton limestone (?).
Burlington, Redrock Point,	Red sandrock.
Burlington, Lonerock Point,	Red sandrock and Hudson River slate.
Appletree Point,	Utica slate.
Colchester Point,	Utica slate.
Law's Island,	Utica slate.
Yew Island,	Utica slate.
Ladd's Island,	Utica slate.
Valcour Island, N. Y.,	Chazy limestone.
Mallett's Head,	Winooski marble (red sandrock series.)
Mallett's Bay, islands in,	Red sandrock.
Stave Point,	Winooski marble and Hudson River slate.
Clay Point,	Champlain clay.
Mouth of La Moille River,	Sand, etc.
Straw Island,	Trenton limestone (?).
Stave Island,	Probably Trenton limestone.
Carlton's Prize,	Trenton limestone.
Rock west of do.,	Probably Trenton limestone.
Providence Island,	Chazy limestone.
Sawyer's Island,	Chazy limestone.
Two Sisters' Islands,	Chazy limestone.

SOUTH HERO AND GRAND ISLE.

Allen's Point,	Sandy.
Martin's Bay,	Trenton limestone, etc.
Merriam's Bay,	Chazy limestone.
McBride's Bay,	Chazy limestone and dikes.

Sawyer's Bay,	Chazy limestone.
Rockwell's Bay,	Trenton limestone.
Porter's Landing,	Trenton limestone. Fine locality for fossils.
Tobias' Landing,	Utica slate.
Northwest corner of Grand Isle,	Utica slate.
Ladd's Point,	Utica slate.
Hyde's Point,	Utica slate.
Pearl's Bay,	Utica slate.
Kibbe's Point,	Utica slate.
Kibbe's Island,	Utica slate.
Adams' Bay and Keeler's Bay,	Utica slate.
Southeast part of South Hero,	Utica slate.
Gull Island,	Hudson River slate.
Fish Bladder Island,	Hudson River slate.
Savage Island,	Hudson River slate.
Milton shore,	Hudson River slate and Oneida conglomerate.
Georgia shore,	Hudson River slate and Onedia conglomerate.
Welden's* Island,	Hudson River Slate.
Potter's Island,	Hudson River slate.
Ram Island,	Silicious slate of the Hudson River Group.
St. Albans Bay,	Hudson River limestone.
St. Albans Point,	Hudson River slate and silicious slate.
Woods Island,	Hudson River slate with a little sparry limestone.
Knight's Island,	Hudson River slate.
Butler's Island,	Hudson River slate.
Diadama Island,	Hudson River slate (mostly sand.)
Hen Island,	Hudson River slate.
North Hero, southeast side,	Utica slate.
Carrying Place, North Hero,	Utica slate.

All that part of North Hero which lies north of the Carrying Place is Utica slate.

Pelot's Point, North Hero,	Locality of fossils in Utica slate.
Kinney's Point, southwest corner of North Hero,	Utica slate.

Along the west coast Prof. Adams found a small exposure of the upper part of the Trenton limestone.

North of Port Kent, N. Y.,	Champlain clay.
Plattsburgh, N. Y.,	Trenton limestone.
Cumberland Head, N. Y.,	Trenton limestone.
Point au Roche, N. Y.,	Chazy limestone.
Isle La Motte, Fisk's Point,	Chazy limestone.
Isle La Motte, south and southeast sides,	Chazy limestone.
Cloak Island,	Disturbed Chazy limestone.
Near both of Hill's Quarries,	Utica slate.
Cooper's Point, Isle La Motte,	Trenton limestone.
Burying Point, Isle La Motte,	Trenton limestone.
Bush Island,	Covered with bowlders.
Blanchard's Point,	Trenton limestone.

The west side of Isle La Motte, from Blanchard's Point to Fiske's Quarries, is composed entirely of Champlain clays. No ledges are reached, even by digging wells.

Chazy, N. Y.,	Chazy limestone.
Rouse's Point,	Champlain clays.

*Sometimes called Ball's Island.

Windmill Point, W. Alburgh,	Sand and pebbles.
Savage Point, W. Alburgh,	Utica slate.
South end of Alburgh,	Utica slate.
Alburgh Springs,	Utica slate.
Hog Island,	Hudson River slate, mostly covered with alluvium.
Highgate Springs,	Trenton limestone.
East part of Missisco Bay,	Limestone of the upper part of the Hudson River Group.

RED SANDROCK SERIES.

GRAY SANDSTONE (Upper Silurian): *Geology of the Second District of New York. By E. Emmons*, page 282; 1842.

RED SANDROCK (Lower Silurian): *Second Annual Report on the Geology of Vermont. By C. B. Adams*, pages 85, 163; 1846.

AGE OF THE MEDINA SANDSTONE: *In a paper communicated to the American Association for the advancement of Science at the Albany meeting*, 1851 (not published). *By W. B. Rogers.*

LOWER PART OF THE QUEBEC GROUP AND EQUIVALENT TO THE ONEIDA CONGLOMERATE (Middle Silurian): *Canada Reports.*

POTSDAM SANDSTONE AND CALCIFEROUS SANDSTONE: *American Geology. By E. Emmons*, Vol. I, Part II, pages 88, 128; 1855.

"OF THE PRIMORDIAL ZONE:" *Remarks on the Fauna of the Quebec group of Rocks, and the Primordial Zone of Canada; addressed to Mr. Joachim Barrande. By Sir W. E. Logan, Director of the Geological Survey of Canada*, Jan. 3, 1861.

The following is an extract from a paper entitled "Notes on the Geological Structure of Western Vermont, etc.," communicated by Prof. William B. Rogers, of Boston, to the American Association for the advancement of science, at its Albany meeting in 1851, but not printed in the proceedings of that Society. It may be useful in the investigation of the history of the red sandrock series:

"The general geological position of the red rocks here spoken of, is clearly seen by following either of the sections, from the western base of the Snake and Buck Mountains, across the trough or valley above described. Here we ascend through the various divisions of the matinal series, from the Trenton to the top of the Hudson River Group as here defined, each marked by characteristic fossils, and all maintaining a nearly uniform eastern dip; and above the latter we find a series of red and greenish and gray sandstones and shales of great thickness, succeeded, where the exposures are unbroken, by arenaceous and argillaceous reddish and gray limestones, alternating with beds of sandstone similar to that beneath.

"Stratigraphically considered, this series of beds occupies the position of the Medina group of New York, or its equivalent, the Levant series of Pennsylvania and Virginia. The sandstones and shales bear a close resemblance to those of the latter, not only in color, but in the profusion of fucoid-like markings which they display on some of the parting surfaces. The series of reddish and gray limestones which rest upon these massive arenaceous beds form an interesting feature in the geology of Vermont. Their alternation with layers of sandstone and shale, and their frequently reddish tint, would lead us to regard them as a continuation of the lower mass under somewhat new formative conditions. In the prolongation of this belt of sandstones and limestones toward the north, as at Winooski Falls, near Burlington, the latter mass is seen to consist, in great part, of a pinkish white fine-grained limestone, which toward the base contains layers of reddish limestone, interstratified with red sandstone,—marking the transition from the arenaceous to the calcareous form of deposit.

"In none of the localities of this calcareous mass, which I have examined, from the flank of Snake Mountain to near the Canada line, have I found any well-marked organic remains. This fact of itself, strongly favors the idea of its being but a peculiar development of the upper portion of the Medina Group. Nor can it be objected to, that this metamorphic action may have caused its present destitution of fossils. Throughout nearly the whole of the series of exposures, extending due north toward the Canada line, it presents a gentle eastern dip, conforming to the subjacent fossiliferous beds of matinal limestone and slate, from which it is separated only by the sandstones above described. From this we infer that it must have been as little exposed as these fossiliferous beds to agencies capable of obliterating its included fossils, and that therefore it has never been in any considerable degree a fossiliferous mass.

"We are further strengthened in the opinion that this calcareous group, with the subjacent sandstone, belongs to the Medina period, by the consideration that the Clinton Group, with which it might otherwise be compared, is almost every where an eminently fossiliferous one. From Alabama to northern New York it is marked by an abundance of fossils. According to Mr. Logan, strata of this age are found in the vicinity of Lake Memphremagog, and, although there surrounded by metamorphic masses, they include a number of fossils in good preservation.

"On the whole, therefore, I think that the limestone and subjacent sandstone of which we are now treating, must be regarded as one formation, and may, with the highest probability, be referred to the period of the Levant rocks or the Medina Group of New York."

The following varieties of rock are associated together in the Red Sandrock series:

1. RED SANDSTONE.
2. WHITE SANDSTONE, OCCASIONALLY VERY COMPACT.
3. SEVERAL KINDS OF BRECCIAS.
4. SEVERAL KINDS OF LIMESTONE, SOMETIMES BECOMING CALCAREOUS SANDSTONES.
5. RED AND VARIEGATED DOLOMITES.
6. GREENISH SHALES.
7. NOVACULITE SCHISTS.
8. SEAMS OF CLAY SLATE.

This formation embraces a great variety of rocks, and there is some difficulty experienced in associating them together, because of the general absence of fossils. The first variety is a reddish brown or chocolate-colored sandstone. It becomes calcareous, and is frequently interstratified with dolomitic layers of corresponding color. The grains of sand composing the rock are often transparent, sometimes mixed with minute fragments of feldspar. A slight metamorphic action has sometimes rendered the grains nearly invisible, and made the whole rock compact. An analysis of this common variety of sandstone from Charlotte gives

Silica,	83.80
Alumina and Peroxyd of Iron,	8.70
Lime,	1.12
Magnesia,	.10
Potassa,	4.59
Soda,	.45
Loss by ignition,	.80
	99.06

This is the common rock of this formation, from which the name of red sandrock, given by Prof. Adams, was taken. It is seen exposed in a range of hills from Bridport to Burlington. In Orwell and Benson there is a sandstone, referred with doubt to this formation, whose color varies between gray and chocolate, and contains many grains of feldspar and other easily decomposing substances.

North of Burlington this variety is mostly replaced by red and variegated dolomites, which have been gradually increasing in amount north of Addison. At Milton a grayish quartz rock appears, probably equivalent to the red rock. The red color is owing to the change in the combination of the iron, produced by heat, as elsewhere.

The other sandstones which lack the brighter colors are distinct from this variety in their appearance. Some beds pass insensibly into a semi-vitreous sandstone, not distinguishable from the quartz rock at the western base of the Green Mountains. These beds may be seen at Monkton, where it is difficult to draw the line between the red sandrock series and the quartz rock, and in Franklin County, in the towns of Milton, Fairfax, Georgia, and St. Albans.

The characteristic beds of the second variety of sandstone are generally very thin—from two to twelve inches—being interstratified with the red sandstones and dolomites. Hand specimens cannot be distinguished lithologically from the Potsdam sandstone. Occasionally there is a considerable thickness of it, as in Highgate, a mile south-east of Saxe's mills, where it must be more than ten feet thick. These beds have probably confirmed some geologists in their opinion that this rock is about the age of the Potsdam sandstone.

Brecciated rocks are very numerous in this series, and there are several kinds of them. A peculiar variety, represented by Nos. $\frac{13}{165}$ and $\frac{13}{166}$, abounds in the east part of Highgate, particularly at Highgate Falls. Prof. Emmons figured a specimen of it in the Geol. Second Dist. N. Y., page 322. The fragments are angular masses of slate, sometimes weighing a hundred pounds, having their own planes of stratification distinct, but not arranged so that the planes of the fragments are parallel with the strata of the breccia. There is a little carbonate of lime in portions of the breccia, as well as occasional traversing veins of calcite, introduced after the formation of the rock itself. It is difficult to imagine how this rock could be formed, and yet preserve so perfectly all the delicate angles of the fragments. This breccia is remarkably compact. It is not found south of Highgate. Further south, near the Lake shore, in Georgia, Milton, and Colchester, the breccias are dolomitic. In Colchester they form a beautiful marble, which is well represented in the State Cabinet, and known as the red, mottled and variegated marbles of Colchester or Burlington.

Further south the breccias diminish in quantity. In the north part of Monkton, Nos. $\frac{8}{174}$ to $\frac{8}{176}$ were obtained of an indescribable but very beautiful variety, intermediate between Nos. $\frac{13}{165}$ and $\frac{13}{166}$, and some forms calciferous sandrock.

Most of the varieties of this formation are more or less calcareous. Hence the variations observed in the fourth variety are very great, and are not generally worthy of specification. In Highgate, where this formation is best developed, the prevailing rock is a dark brown, massive, impure limestone, forming numerous small hills with mural sides. This calcareous rock continues to Burlington, where it is interstratified with sandstones. In Georgia and Milton, this variety becomes a calcareous sandstone, closely resembling the calciferous sandrock of the Lower Silurian. In Hinesburgh, Monkton, etc., there are beds of limestone, occasionally nearly pure carbonate of lime, as at Hinesburgh Center, where some of it is manufactured into quicklime. We think it not unlikely

that this belt of limestone runs through the whole of Hinesburgh and Monkton, connecting together the two great deposits of the Eolian limestone. Other beds probably run through and may belong to the same belt, but repeated upon the numerous folds. The limestone of this formation, between Burlington and Highgate, is embraced under the fifth variety, dolomitic. For the analysis of the Winooski marble gives

Silica, . . .	10.304
Alumina and iron, .	12.251
Carbonate of lime, .	35.310
Carbonate of magnesia,	42.235
	100.100

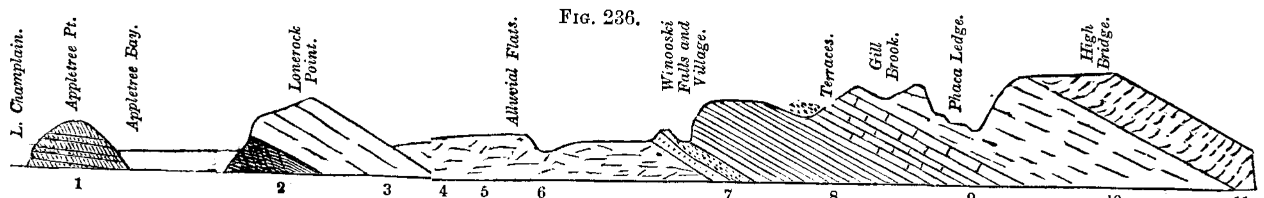
The magnesia is in excess, and the silica is combined with the alumina and iron, there being less than two per cent. of iron present. It is surprising that this complicated rock should be decomposed with so great difficulty. The colors of this dolomite vary from bright red through chocolate, brown, and greenish brown, to grayish white. It is usually mottled, and sometimes brecciated, when it is penetrated by white veins of calcite. We have called this variety the *Winooski marble;* not to multiply local designations, but to designate a peculiar variety of the red sandrock series, using the name by which it is known in economic geology. To gain a proper idea of the different varieties of the Winooski marble, we refer to the detailed accounts of Sections IX, X, XI, XII and XIII, where the varieties are described in a descending order.

The greenish shale and novaculite schists are very much alike. The former are interstratified with strata of sandstone in the northern part of the terrain, particularly at Charlotte, where cleavage planes are abundant in them. The latter form masses of rock by themselves in the east part of Swanton, and the north part of Franklin. They pass into clay slate. These seams of clay slate are of sufficient extent to deserve notice as a distinct variety.

The rock that we call talcose schist or talcose grit, in Vermont, is found in this group. As shown elsewhere there is generally very little magnesia present. Specimens of this green schist are found in the southeast part of Burlington.

Having specified the characters of the principal varieties of the rocks composing the red sandrock series, we proceed now to give a few local sections to show the relative position of these varieties to one another. We select from a large number of drawings on hand. Fig. 236 represents the character of the rocks between Appletree Point in

Fig. 236.



Section in Red Sandrock from Appletree Point to Penniman's Lime Kiln.

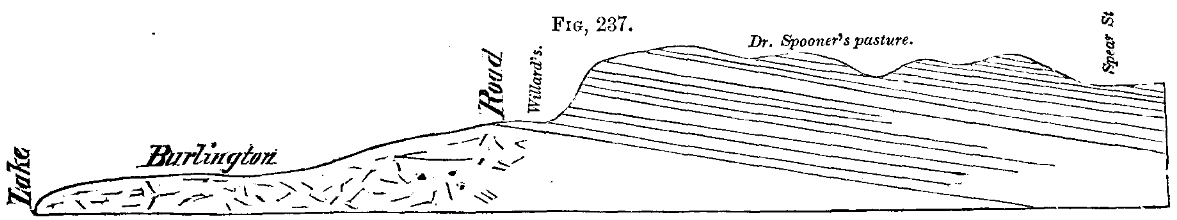
1 Utica slate.
2 Hudson River slate.
3 Winooski limestone.
4 Marshy ground.
5 Intervale.
6 Winooski River.
7 Red sandrock.
8 Silicious limerock.
9 Stratified quartz.
10 Silicious limerock.
11 Eolian limestone.

Phaca Ledge refers to the fact that at this point there is an excellent locality of rare plants, conspicuous among which is the *Phaca Robbinsii* (Oakes.)

Burlington, and Penniman's lime kiln, in Colchester. It was originally drawn very carefully by Prof. Thompson.

The different varieties are specified in the explanations below the figure. But upon a part of this section the red sandrock series is concealed by alluvium. Therefore we introduce Figs. 237 and 238 to show what rocks crop out at Burlington, along the line

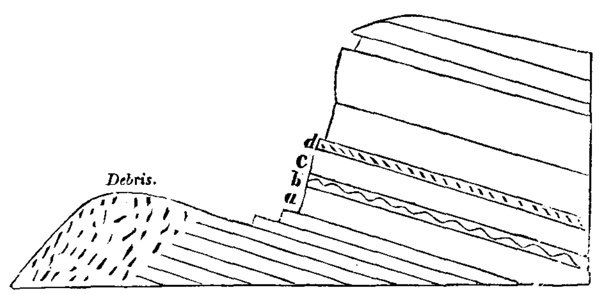
Fig, 237.



Section from the lake, through Willard's Ledge to Spear Street.

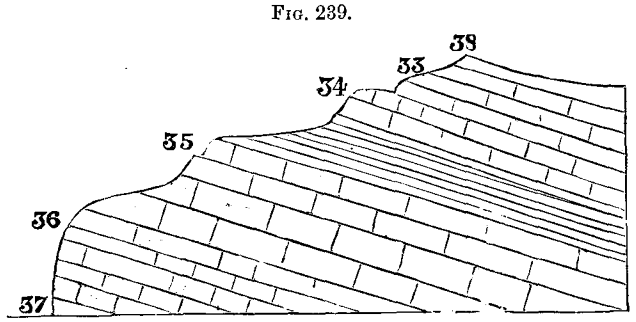
of the strike of those rocks that would be found in the marshy and alluvial interval of the preceding sketch, if it be extended. The ledges are mostly varieties of red sandstone. Fig. 238 shows what the particular layers are at Willard's quarry. *a* is jointed red sandrock; *b* is a contorted stratum of the same, seven inches thick at the northeast opening of the quarry, and was about twelve feet below the top of the quarry in 1847. *c* is variegated sandstone; *d* is a slaty rock with a green surface. The other layers are the ordinary flagging stone derived from this formation. The section ending at Spear Street, joins No. 7, in Fig. 236, after a short interval.

Fig. 238.



Willard's Ledge, N.E. opening.

Fig. 239.



Quartz Ledge below the High Bridge.

Fig. 239 represents an enlargement of No. 9, in Fig. 235, east of Winooski Falls, in Colchester. The bluff rises very abruptly from the eastern margin of the first terrace, above Winooski Lower Falls. The first precipice of about twenty feet, is nearly perpendicular. Two or three feet at the base (37), are silicious limerock. The rest of the perpendicular wall (36), is nearly white quartz, formerly used for the manufacture of glass in Burlington. For a rod or more east of the summit of this precipice, the rocks are covered by soil, the ground gradually rising to No. 35, which is composed of brown quartz. No. 34 is slaty sandrock very evenly stratified. No. 33 is quartz rock, overlaid by calciferous sandrock, massive, and without any marks of stratification. The whole thickness of this ledge of quartz is fifty feet.

Divisional Planes.

A few observations respecting joints, cleavage and foliation planes, have been recorded. Jointed planes are quite common, crossing the strata. The following are a few of them:

Locality.	*Strike.*	*Dip.*	*Observer.*
Milton, northwest corner,	N. 20° E., most common,	90°,	C. H. H.
Milton, northwest corner,	N. 55° E.,	90°,	C. H. H.
Burlington, Redrock Point,	N. 50° E., most common,	90°,	C. H. H.
Burlington, Redrock Point,	N. 25° E.,	90°,	C. H. H.
Burlington, Redrock Point,	E. and W.,	90°,	C. H. H.

At the last locality there were several perpendicular excavations in the ledge, which run N. 50° W. They are from three to twelve feet in width. They appeared much as if dikes of igneous matter had once filled them. But the absence of any evidences of trap and porphyry in them lead us to suppose that they were washed out by the water of Lake Champlain between parallel joints like some of the *fiords* upon our coast; for example, the so-called *Purgatory* at Newport, R. I. The east and west system of joints crosses these fiords transversely.

Cleavage planes as well as joints are abundant in this rock, but the number of observations of both these structural peculiarities is miserably small in proportion to their importance.

STRIKE AND DIP OF THE STRATA.

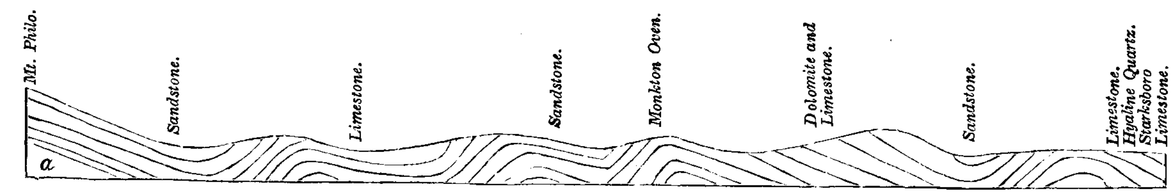
Locality.	*Strike.*	*Dip.*	*Dip of Strata.*	*Observer.*
Charlotte, Mutton Hill,	N. 20° W.,	43° E.,	15° E.,	C. H. H.
Richmond, northwest part,	N. 10° E.,	50° E.,	23° E.,	C. H. H.
Highgate Falls,	N. 30° E.,	90° E.,		C. H. H.
Benson, and Orwell,			10° E.,	C. H. H.
Bridport, northeast part,	N. 20° E.,		30° E.,	E. H., etc.
Top of Snake Mountain Addison,				C. B. A.
Addison, top Snake Mountain,			5° E.,	C. H. H.
Addison, northeast part,	N. 20° E.,		25° E.,	C. B. A.
Waltham, west part,	N. and S.,		20° E.,	C. B. A.
Waltham, west part,	N. and S.,		20° E.,	C. B. A.
New Haven, southeast of village,	N. 10° E.,		25° E.,	C. H. H. and E. H., jr.
New Haven, north of village,	N. 10° E.,		65° W.,	C. H. H. and E. H., jr.
New Haven, east of village,	East of north,	35° E.,	5° E.,	C. H. H.
Monkton, south part,	N. 30° E.,		30° W.,	C. H. H. and E. H., jr.
Monkton, near R. Baldwin's,	N. 30° E.,		25° W.,	C. A. W.
Monkton, near do.,	N. 60° W.,		10° N.E.,	C. A. W.
Monkton, east part,	N. and S.,		44° E.,	C. B. A.
Monkton, southwest part,	N. and S.,		20° E.,	C. B. A.
Monkton, southwest corner,	N. 10° E.,		55° W.,	C. B. A.
Monkton, northwest corner,	N. and S.,		20° E.,	C. B. A.
Monkton, northwest part,	N. and S.,		20° E.,	C. B. A.
Monkton, Oven,				
Monkton, between east and west lines of the town, there are four anticlinals and four or five synclinals, running N. and S. through the town, into Hinesburgh,				C. H. H.
A multitude of observations there need not be added to this list.				
North Ferrisburgh,	About N. and S.,		4°–5° E.,	C. H. H. and E. H., jr.
Charlotte, near village,	N. 20° W.,	43° E.,	15° E.,	C. H. H. and A. D. H.
Charlotte, T. A. Williams',	N. 15° W.,		16° E.,	C. H. H. and A. D. H.
Charlotte, D. Ball's,	N. 45° E.,		80° S.E.,	C. H. H. and A. D. H.

Charlotte, near do.,	N. 20° W.,	26° E.,	C. H. H. and A. D. H.
Charlotte, east part,	N. 9° E.,	35° W.,	C. H. H. and A. D. H.
Charlotte, east part,		28° E. and 5° E.,	C. H. H. and A. D. H.
Charlotte, Pease Hill,	N. and S.,	15° E.,	C. B. A.
Charlotte, middle,	N. 10° W.,	20° W.,	C. B. A.
Charlotte, west part,	N. 25° W.,	16° E.,	C. B. A.
Charlotte, east part,	N. 40° E.,	70° S.E.,	C. B. A.
Charlotte, south part,	N. and S.,	50° W.,	C. H. H.
Charlotte, south line,	About N. and S.,	5° E.,	C. H. H.
Hinesburgh, west part,	N. 10° E.,	65° W.,	C. H. H. and A. D. H.
Hinesburgh, east of do.,	N. and S.,	45° E.,	C. H. H. and A. D. H.
Hinesburgh, center, west of,	N. 35° E.,	25° W.,	C. H. H. and A. D. H.
Hinesburgh, southwest corner,	N. and S.,	10° E. & 10° W.,	C. B. A.
Hinesburgh, southwest part,	N. 12° E.,	8° W.,	C. B. A.
Hinesburgh, southwest part,	N. 5° E.,	35° W.,	C. B. A.
Hinesburgh, west part,	N. and S.,	30° W.,	C. B. A.
Hinesburgh, west part,	N. and S.,	28° W.,	C. B. A.
Hinesburgh, south middle part,	N. and S.,	15° E.,	C. B. A.
Shelburne, near center,	N. and S.,	17° E.,	C. B. A.
Shelburne, east of center,		7° E.,	C. H. H. and E. H., jr.
Burlington, southwest part,		40° E.,	C. H. H.
Burlington, Redrock Point,	N. 20° E.,	13° E.,	C. H. H.
Burlington, do., extreme end of Point,	N. 20° E.,	15° E.,	C. H. H.
Burlington, west part,	N. and S.,	8° E.,	C. B. A.
Burlington, generally,		8°–12° E.,	Z. T.
Burlington, Bluff Point,		20° E.,	Z. T.
Burlington, Willard's quarry,		20° E.,	Z. T.
Winooski Falls,	N. & S. (variable),	5°–10° E.,	C. H. H. and A. D. H.
Winooski Falls, east part,		8° E.,	C. H. H.
Colchester, High Bridge,		18° E.,	Z. T. and C. H. H.
Burlington, Lonerock Point,		6°–8° E.,	C. H. H. and A. D. H.
Burlington, northwest part,	About N. and S.,	6° E.,	C. H. H. and E. H., jr.
Milton, southwest corner,		6°–8° E.,	C. H. H.
Milton, northwest corner,	N. 4° E.,	10° E., 6° E.,	C. H. H.
Georgia, Caldwell's,	N. 30° E.,	42° S.E.,	C. H. H.
Georgia, Robinson's,	N. 30° E.,	15°–20° S.E.,	C. H. H.
Georgia, Parker's, trilobite locality,		10°–12° E.,	C. H. H.
St. Albans, northwest from village,	N. 50° E.,	42° E.,	C. H. H.
St. Albans, northwest part,		10°–12° E.,	C. H. H.
St. Albans, west part,		5°–6° E.,	C. H. H.
Swanton, east part,		2°–25° E.,	C. H. H.
Swanton, center,		25° E.,	C. H. H.
Swanton, Charles Bullard's,	N. 50° E.,	16° S.E.,	C. H. H.
Highgate Falls,		5° E.,	C. H. H.
Highgate, middle part,		12°–15° E.,	C. H. H.
Highgate, middle part,		4°–5° E.,	C. H. H.
Highgate, Church's,		20° E., 36° W., 90°, 55° W. and 10° E.,	E. H. and C. H. H.
Saxe's Mills,	About N. and S.,	6°–8° E.,	C. H. H.

Thus the prevailing dip of the strata seems to be easterly, and consequently the general position of the formation is the same. It is the ninth belt of rock surrounding the Laurentian nucleus in New York. Sections VIII. to XIII. and Fig. 167 illustrate the position of this rock, both by itself and as it connected with other groups. Section VIII. shows several plications in the strata between Charlotte and Hinesburgh.

Fig. 240 shows a similar section, parallel with Section VIII, and six miles south of it. There are five distinct anticlinals upon it in a distance of six miles. The east end of the section is near the east line of

Fig. 240.

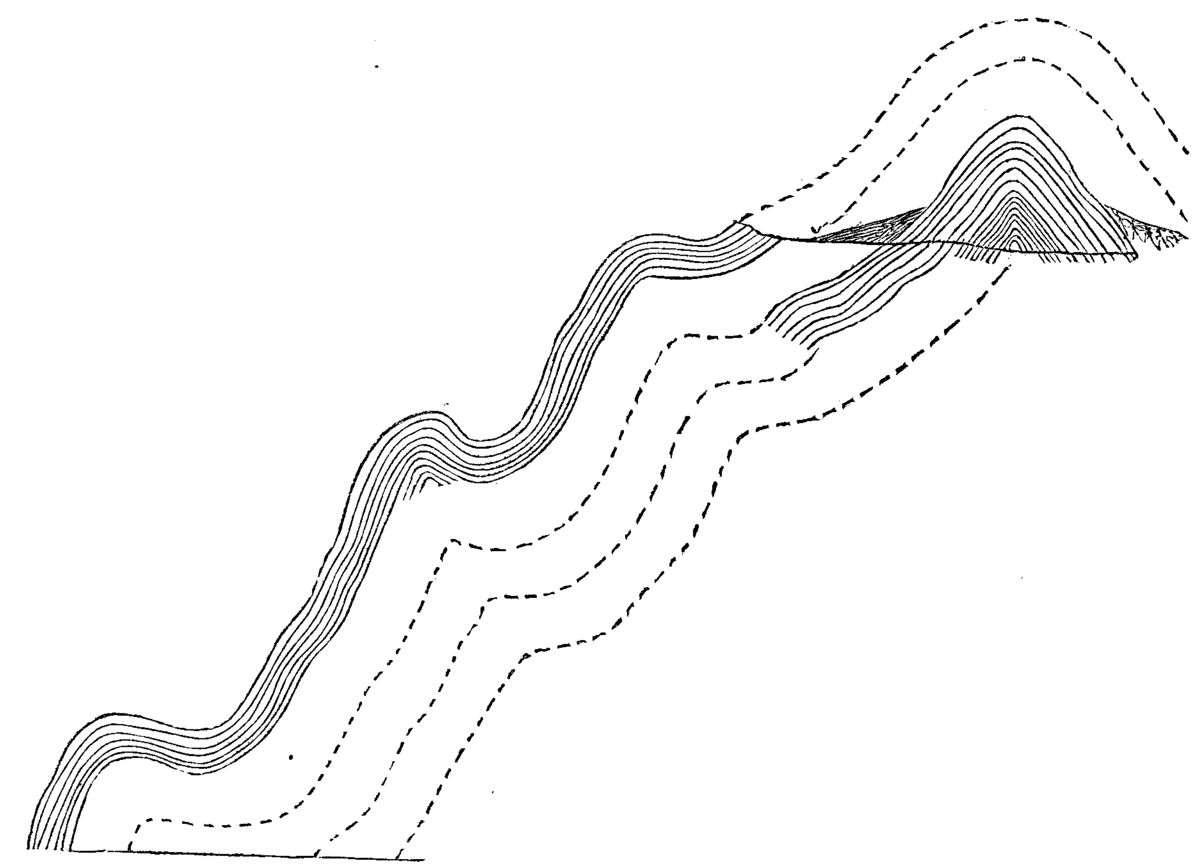


Section through Monkton in Red Sandrock.

Monkton, not far from Rockville, where there are strata of coarse limestone overlapping a ridge of semi-vitreous quartz; the latter forming the termination of the great quartz range lying at the west base of the Green Mountains. This limestone dips away from the quartz rock upon both sides. The remainder of the section is the ordinary red sandstone, occasionally white, except beds of limestone and red dolomites at the "Ridge" and the west part of the town.

The "Monkton oven" has been partially figured by Prof. Adams in his Second Annual Report, page 165. Fig. 241 represents the same fold with its continuation for several hundred feet down the western side of the

Fig. 241.

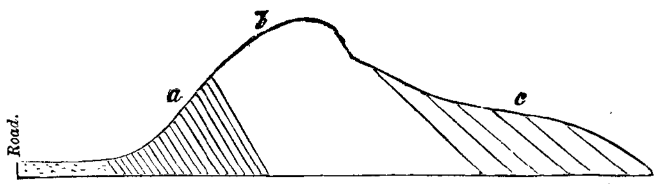


Natural section of Red Sandrock, Monkton.

hill. This sketch was drawn by Prof. Adams. The rocks, though many of them are pure quartz, and their strata sometimes exceeding a foot in thickness, do not appear to be fractured or have their continuity at all disturbed. One of the strata is argillaceous, with cleavage planes perpendicular to the planes of deposition. The name of *oven* is given because there is an excavation in the crest of the fold, which with the arch above resembles an old-fashioned oven.

The dip of the strata sometimes varies greatly in the same hill, when the dip is all in the same direction, as at Glebe Hill, in Charlotte. The dolomitic limestones occupy a lower and more highly inclined position than the overlying sandstones. Fig. 242, drawn by Prof. Thompson, illustrates the structure of this hill: *b* is the dolomite, *c* the red sandstone, and *a* is underlying Hudson River slate. Probably the dip of the slates is mostly obscured by metamorphosis, and it is the cleavage planes which are shown upon the section.

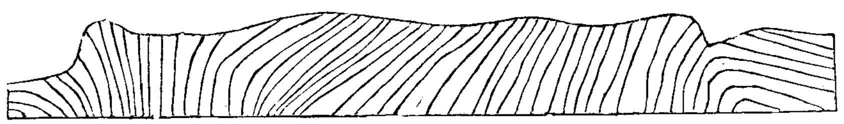
Fig. 242.



Glebe Hill, Charlotte.

East of Highgate Springs. near the trilobite locality, there is a singular plication of the strata, which, at the time of our exploration in 1858 we were inclined to regard as a local disturbance. The position of the strata is represented in Fig. 243. The section is well exhibited by the abrupt precipitous termination of several ledges at the south side of a hill. The drawing is a copy of one large ledge fifteen or twenty rods long. At the east end, the strata dip only 10° E., in conformity with the general position of the terrain. The same strata traced westward, gracefully dip to the west, at first 55°, and are then perpendicular. Most of the section has a westerly dip of about 36°. At the west end of the ledge the curve is continued so that some of the strata are inverted, and dip to the east beneath older layers. How far this inversion extends to the westward will require further investigation. We thought it to be of limited extent at the time of our observation; but if it was extended further it would seem to be wonderfully in agreement with the opinion that the red sandrock series is part of the Potsdam sandstone. For if the Potsdam sandstone is inverted at the locality of Fig. 243, the rocks westward should be coarse limestones gradually ascending to the Trenton limestone. Such is the case exactly. The coarse limestones west of the red sandrock would very well agree with the calciferous sandrock, and just east of Highgate Springs there are fossils of the Black River limestone followed by Trenton limestone fossils at the Franklin House. We find a record in our note books of the great lithological similarity of these coarse limestones to the calciferous sandrock. Upon the other view the Hudson River slates ought to be developed between the Springs and the trilobite locality. We could find nothing of the kind in our explorations. We should not wish to believe the view we have just presented of the inversion of the strata without further examination, but mention it as an excellent place to test the value of the different theories.

Fig. 243.



Section of Red Sandrock, in Highgate.

Range, Extent and Thickness.

In New York there is an interrupted belt of Shawangunk grit, occasionally very thick and then reduced to a mere edge, which we suppose to be the southern prolongation of the Vermont range of red sandrock. Their directions and general characteristics coincide. In Vermont it appears first in Orwell and Benson, in one or two hills near their mutual boundary line. It is somewhat uncertain, however, whether the sandstones in Orwell and Benson are anything more than a bed in the clay slates.

In the south part of Shoreham, at Rich's mills, are the first out croppings of this group of rocks which we have seen at any point north of Benson. The rocks referable to the red sandrock series at Rich's mills, is a whitish sandstone, intermediate, in lithological character, between Potsdam sandstone and quartz rock. This sandstone is about twenty feet thick, interstratified with coarse limestones, which possibly belong to the same series. These beds of sandstone appear again at the village of Shoreham. A mile or two north of the village the sandstone is thicker than at any locality southward of it. It closely resembles Potsdam sandstone. The rocks north of the latter locality have a mongrel character, being intermediate between sandstone and limestone. The most satisfactory ledge in the northeast part of Shoreham, or the one which corresponds more nearly to the rocks of the series under consideration, is upon the east bank of the Lemonfair River, at H. De Long's house. It is a high bluff of gray calcareous sandrock, lying nearly horizontal, like the west edge of the whole range of red sandrock. We have extended the color of the red sandrock from the north upon the map, so as to cover all these ledges—though with some misgivings.

But near Mr. C. Gale's house, upon the east line of the town of Bridport, appears a great ledge of rocks, the continuation of the calcareous gray sandstone of Shoreham, which no one can doubt belongs to the red sandrock series, as it possesses the characteristic color and composition of the red sandstone.

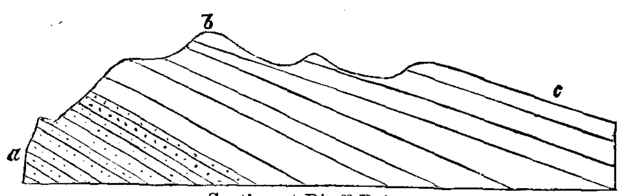
It is moreover the south end of the hill which gradually rises into the Snake Mountain in Addison, the highest summit in the range from Bridport to Burlington. As one stands upon the top of Snake Mountain, and views one after another the peaks with their sharp points and steep western mural faces, he sees most distinctly their geological character. Snake Mountain, Buck Mountain, Marsh Hill, Shell House Mountain, Mount Fuller, Mount Philo, Glebe Hill, Pease Hill, and Mutton Hill, all belong to one great geological sheet, that formerly extended much further westward towards those Laurentian rocks forming such conspicuous mountains in New York; and covering up the several successive concentric bands of lower silurian rocks beneath. The tough sandstone has resisted decomposition, and its ragged edges project pointedly to the west in proportion to the compactness of the ledges and their comparative freedom from erosion; while the softer shales and limestones beneath have mostly disappeared, forming the valley of Lake Champlain, as well as the foundations of the successive range of mountains we have just mentioned.

The east sides of these mountains slope gradually to the east because of the dip of the rock. In Monkton, the range suddenly widens greatly. This is because the same rocks are repeated in successive undulations, as instanced upon Fig. 240. A spur runs down from the southeast corner, as seen upon the map, into the south part of New Haven, and is interstratified there with the crystalline white Eolian limestone. In Chittenden county the width of the sandstone diminishes greatly, being almost entirely cut off in Shelburne. This narrow belt, however, is no thinner than the rest of the range. It is reduced by erosion to as small a width as is possible, and there are no undulations in the strata to increase its lateral dimensions.

Prof. Thompson spent many years of his life upon this formation in Burlington, and therefore we quote from his notes what he has said respecting this series of rocks in Chittenden County:

" The western border of this formation consists of an interrupted series of uplifts, varying from fifty to nine hundred feet above the Lake; and through this whole extent the rock consists of a reddish or reddish-gray sandstone. At the Sugar Loaf, Glebe Hill, and Mutton Hill in Charlotte,* and through Shelburne, it appears to be a nearly pure silicious red sandstone, exhibiting very distinct strata. From Lonerock Point† northward, the rock is considerably calcareous, and the marks of strata are nearly obliterated. Its color is variegated, and in many places variegated with reddish-gray and yellowish-white. At Lonerock Point, and at several places in Colchester, this rock is seen lying upon the black slate [Hudson River]; and at the former place fragments of it are found imbedded in the slate. At Bluff Point the lowest strata visible have very much the appearance of the strata further north, above mentioned, but the stratification is very distinct. Fig. 244 represents a section running through it. From the west end, near the water, is red dolomite. *b* exhibits shrinkage cracks, and *c* fucoids. The dip is 25° E. near the water at *a*; but is 10° E. at *c*.

Fig. 244.



Section at Bluff Point.

"At the Sugar Loaf in Charlotte, the lower strata of the red sandstone formation for ten or twelve feet above the black slate are interstratified with green shale. The dip of the red sandstone proper in Burlington varies from about 8°–12° E., with the exception above named at Bluff Point. The places where it may be seen to best advantage are Willard's Ledge [Fig. 237], half a mile south of the village, and at the foot of Winooski Falls [in Fig. 236.] The strata at these places vary in thickness from an inch to two feet, and the different strata vary considerably in the fineness of the materials and the shades of color. At Willard's Ledge there is one stratum, about four inches thick, of almost pure white quartz, which may be traced for a long distance. Other strata are almost black, while others are slaty, with a green surface; others are contorted, variegated and jointed. The position of several of these are shown in Fig. 238. *b* is in places very compact and beautiful, having some resemblance to agate. Between the strata of sandstone at this locality are interspersed at several places extremely thin layers of quartz, some colorless and nearly transparent, others more opaque, bearing dendrites upon their surfaces. The upper strata at Willard's Quarry are nearly white and quite calcareous; and they become more and more calcareous till the silicious matter is all gone, and they are nearly pure unstratified limestone [Eolian.]

"At Winooski Falls the red sandstone passes equally sudden into gray sandstone with more carbonate of lime. Beautiful ripple marks occur in many of the strata of red sandstone both at Winooski Falls and Willard's Ledge. What appear to be impressions of rain drops are frequently met with, and at Winooski Falls, Redrock Point, and Bluff Point, fucoids are abundant.

"Half a mile east of the gray calcareous sandstone at Winooski Falls is a sharp uplift, marked 8 on Fig 236, and exhibited upon a larger scale in Fig. 239. It is almost wholly brown quartz. It is succeeded on the east by a calcareous sandrock, in which the traces

*There is also a small patch of gray sandstone belonging to this formation upon a small hill west of the general range, half a mile south of Charlotte Village.—C. H. H.

†Sharp Shins.

of stratification become more obscure until they are lost in the limestone at the (R. R.) High Bridge. The strata at Winooski Falls probably pass under the quartz ledge just mentioned, although the strata are covered with alluvium at the supposed line of contact.

"To the northward of Winooski River the red sandstone strata are either concealed, or are mostly without the red coloring matter which characterizes them to the southward. The quartz strata resembling those above Winooski Falls are finely exposed in numerous places to the east and northeast of Mallett's Bay. In one place a ledge of pure stratified quartz, twenty-five feet thick, is exposed. Northeast of these localities the silicious dolomites are extensively developed, but are too silicious to make good quicklime."

There are three localities of the stratified quartz in Colchester: in the range of the red sandrock, southeast of Mallett's Bay, about a hundred rods from the water; in the silicious limerock on the east side of the road, a mile north of the Methodist Church, in the west part of the town; and at a hundred rods west of the stage road from Burlington to Milton, on the road to Clay Point.

We have not evidence before us to decide positively whether this quartz rock, with its associated dolomites, passes from the northwest part of Colchester west of Cobble Hill, to connect with similar rocks at Milton Falls, and thus with the group of rocks which we shall describe under the name of talcose conglomerates. We have not ventured to connect them upon the map, but can hardly doubt their connection. But the western range passes along the border of Lake Champlain, from Mallett's Bay to St. Albans Bay, as it has been examined all along the coast, and has been crossed twice in Milton, twice in Georgia, and several times in St. Albans. The rock is generally highly colored, and is mostly calcareous. It is massive, sometimes appearing destitute of stratification. At St. Albans it is almost sandstone, between the bay and the central village, with scarcely any dip. It passes now away from the lake east of Rich's quarry, in Swanton, and east of Swanton Falls, growing more silicious, until in the north part of Highgate, on the Teachirt hills, it is mostly red quartz rock. But east of the Teachirt hills it is a dark brown silicious limestone, succeeded in turn by a curious breccia, already described.

The thickness of the red sandrock series, upon Prof. Adams' section of Snake Mountain, is more than 500 feet; and this does not include the whole of the rock, because a few feet of the higher portion may have been worn away. Prof. Thompson estimated the thickness of this group, at Burlington, to be 300 feet. This would give the thickness for the constituent members about as follows, beginning at the top of the series:

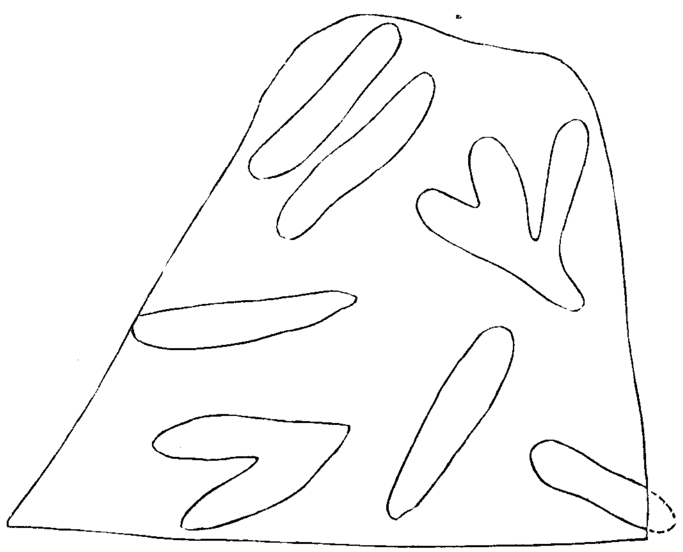
Silicious limerock,	75 feet.
Brown quartz,	50 feet.
Calcareous sandstone,	60 feet.
Red sandstone,	75 feet.
Winooski marble,	40 feet.

We think that the thickness is somewhat greater in the northern part of the State, but do not feel able to state the exact thickness, as all the calculations based upon the observed dips give a much larger thickness than seems probable. For instance, the thickness of the whole group of rocks between St. Albans Bay and the eastern limit of the talcose conglomerates, as calculated, amounts to several thousand feet; but in Canada these rocks are four thousand feet thick, and our calculations seem to agree with these results.

FOSSILS.

This rock is very barren in fossils, and those found are very obscure. First we will mention the plants. These are all *fucoids*. The most distinct among them is figured in outline in Fig. 245, reduced to one-half the natural size. It appears to be related to the *Fucoides chemungensis*, figured by Prof. Hall from the Chemung group. The specific differences are not great, but the fact that it occurs in an entirely distinct group of rocks is probable evidence that it is a distinct species.

Fig. 245.

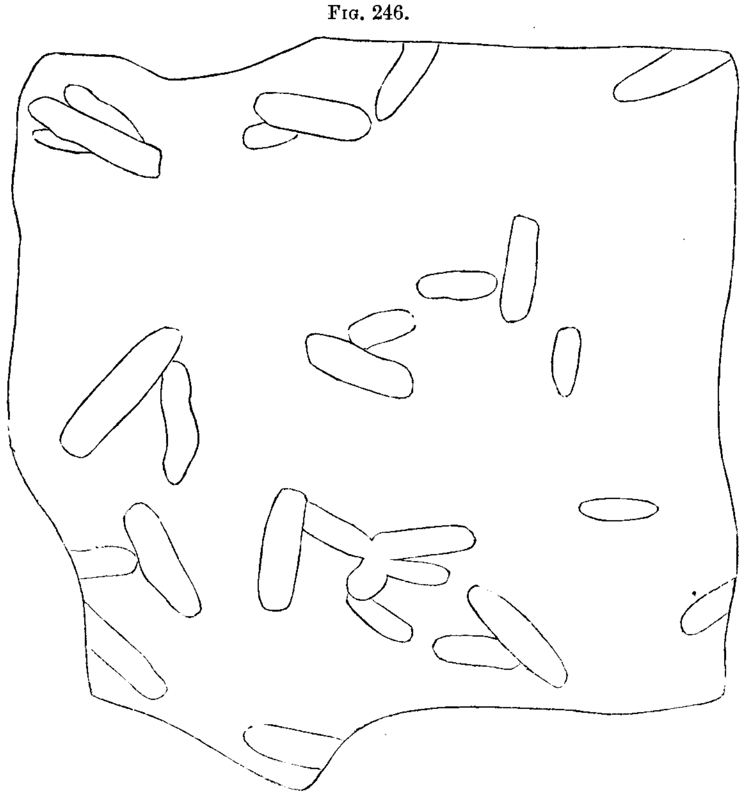


Fucoids, reduced ½. Shelburne. Red Sandrock.

There are one or two smaller species of this genus which are not represented in any figures, but are to be found in the State Cabinet with the other fossils of this group.

The localities of the first species (Fig. 245) are in Addison, Bridport, and probably along the whole range of the western belt of the series; but they are developed unusually well at Shelburne, an eighth of a mile north of the depot, on the road to Burlington. There the smaller species also occur. At Willard's Ledge, in Burlington, there are some similar fucoids, which were regarded as *ichnoid impressions* by Prof. Adams. Fig. 246 represents them, as drawn by Prof. Adams.

Fig. 246.



Fucoids, Willard's Quarry.

It is curious that the elevations called fucoids are sometimes composed of a different substance from the overlying strata (for these impressions are the wrong side up for footmarks), and they rest in sockets, as it were, precisely as the rock would appear if an impression having the shape of the different fragments of the vegetable had been made, and the depression been filled with the material of the next stratum as it was deposited, and then, after the stone was hardened, the whole had been inverted. Often the stone is decomposed, except the fucoids, which remain exceedingly prominent. Specimens of this kind are found in the Cabinet, and there are very fine specimens of it in the Geological Cabinet of Middlebury College.

Other kinds of fucoids occur in this rock, of which there are no specimens in the Cabinet. In hastily passing through Monkton, we noticed a fucoid resembling somewhat the *Arthrophycus Harlani* of the Medina sandstone group. At St. Albans we saw an obscure fucoid in fragments upon some flagging stones, different from any described species.

Of animal remains, trilobites and one or two shells have been found at Highgate; and Prof. Thompson adds, "fragments of crinoidea." Prof. Adams sent specimens of these trilobites to Prof. Hall, in 1847, who then communicated the following information respecting them:

"I have examined the fossils, and, as far as I can determine, they are all of the central portion of the buckler of a trilobite, with a prominent narrow lobed glabella. The cheeks have been separated at the facial section, so that we have not the entire form of the head. The course of the facial section indicates that it terminated on the posterior margin of the buckler, and the glabella is narrower in front than behind. These two characters are inconsistent with *calymene, phacops, or asaphus*, the common genera (as well as with several other genera) of our strata, but they belong to *conocephalus* and *olenus*. I am inclined to regard this fragment as part of a *conocephalus*, of which I have not before detected a fragment in our rock. From its isolated character, therefore, I am able to infer little regarding its real geological position. The form known to me most nearly like this one, is in the Clinton group of this State. I regret that more species could not have been found, or that some forms in the preceding strata could not be obtained to compare with others already known.

"The meager information of the two known species of *conocephalus* is likewise an objection to any geological inference from the discovery of a species. All we know is that they are found in Greywacke, in Germany or elsewhere, and the position of the Greywacke is too dubious and ubiquitous to be of any importance in such a case. I regret exceedingly that I am unable to give only this meager and unsatisfactory information, and also that I have not had the satisfaction of seeing the locality."

The locality of this fossil is in Highgate, about two miles east of the springs, and the same distance from Canada, directly east of the house of Jacob Church. It was discovered more than twelve years ago by Messrs. S. R. Hall and Z. Thompson. The inclosing rock is a hard red sandstone, containing a very small per centage of lime; for it is only where the rock has decomposed somewhat that the fossils are seen. In some specimens the rock seems to be almost made up of fragments of animal remains. Besides the trilobites two specimens of a shell (which were burnt up in the old State House) were obtained, resembling *atrypa hemispherica* (now *Leptocœlia hemispherica*) of the Clinton Group of New York.

Certain *inorganic* fossils are common in this rock, as impressions of rain drops, ripple marks, and shrinkage cracks. These indicate that this rock was formed in very shallow water.

Mineral Contents.

Distinct minerals are seen in the red sandrock. The silicious limestone frequently contains very fine limpid hexagonal crystals of quartz, disposed in geodic cavities, as at Winooski Falls.

Rev. S. R. Hall reports a vein of red hematite in the northwest corner of Milton, upon Lake Champlain, resembling that in Fairfield.

In Colchester and Swanton there are a few deposits of the brown hematite, described under *Tertiary Rocks*, which have been derived from the red sandrock series of strata.

In the northwest part of Swanton a company that mined for lead discovered no lead, but threw out a considerable of that variety of asbestos called mountain leather or mountain cork (Nos. $\frac{13}{163}$, $\frac{13}{164}$.) It is on the land of a Mr. Bullard.

Deposits of bog iron ore are not infrequent in low lands upon this formation. The iron has been derived from the sandstones and the limestones, much like the iron of tertiary age.

Geological Position and Equivalency.

For the position of the red sandrock series we need only to refer to Figs. 167, 230, 234, and Sections VIII. to XIII. Without an exception it rests upon the Hudson River Group. The stratigraphical evidence goes to show that the red sandrock is of the age of the Medina sandstone or Oneida conglomerate. This was the original view of Prof. Emmons, and has since been sustained by Professors C. B. Adams, W. B. Rogers, and Sir W. E. Logan. It is certainly an objection to this view that the characteristic fucoid, *Arthrophycus Harlani*, of the Medina sandstone, has never been found in it.

Professor Emmons originated a different view after the adoption of his Taconic system, and regards it, sometimes as the calciferous sandstone, and sometimes the Potsdam sandstone. He did not rely, however, upon Palæontological evidence, but upon its stratigraphical relations to the black slate of the Taconic system.

The Canada Survey provisionally named the prolongation of the red sandrock into Canada "the Quebec Group." One hundred and thirty-seven species of fossils, having a primordial aspect, have been obtained from this group at Point Levi, near Quebec; and the Survey have changed their views respecting its age, and now agree with Prof. Emmons in placing it at the base of the Lower Silurian system. These views are proclaimed in a letter from Sir Wm. Logan to Barrande, published in this Report under the "Georgia Slate." If the view taken by this letter be adopted, it will be necessary to suppose the existence of a great fault, extending from Quebec through the whole of Canada and Vermont, and perhaps to Alabama. Its course through Vermont would correspond very nearly to the western boundary of the red sandrock formation.

It seems that the *conocephalus*, one of the most important genera in establishing the primordial character of the Quebec group, was discovered in Vermont by Messrs. Z. Thompson and S. R. Hall, in 1847, long before its discovery in Canada, and before its value in palæontological research was known in Europe. (*See Prof. James Hall's letter to C. B. Adams, on page* 339.) Had the specimens been more perfect they would have been described long ago, and might have started the present controversy earlier than its recent inception.

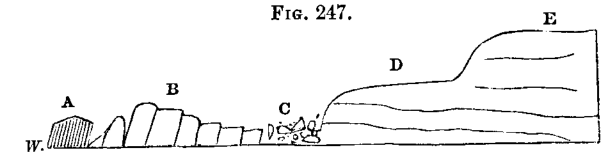
We have used the name of red sandrock for this series of strata, that our Survey may not be committed to either side of the discussion before the result is clear to every mind. And we have presented the arguments in full upon both sides of the controversy, so that our readers may decide for themselves the question of the age of the red sandrock, and that, too, from original sources.

Professor Emmons holds that the red sandstones of this age rest unconformably upon the slates beneath, throughout the State, and regards this as a strong argument in favor of his views. Even if the premises were granted we do not think his conclusions would follow.

We add in this place a few rough notes we made in 1859, concerning the relations of these grits and slates. We do not feel disposed to endorse them now, but quote them as an exposition of theories which have been held regarding these rocks, and are not yet proved to be false.

"It is a remarkable fact that the Hudson River slates do not appear between the Trenton limestone at Highgate Springs, and the Oneida grit (red sandrock) at Saxe's Mills, two or three miles east; while still further east, where the grits have been worn through, the slates appear beneath, decidedly unconformable. Fig. 247 illustrates this position.

Fig. 247.



Section in Highgate.

Explanation of Fig. 247.

A Clay slate, dip 67° W., strike N. 15° E.
B Coarse limestone (red sandrock), dip west.
C Debris from D and E.
D Gray sandstone (red sandrock), dip 5° E.
E Coarse limestone (red sandrock), dip 5° E.

The slate, A, lies in a valley between two hills of red sandrock, and it shows itself in two or three places. The ledges of sandstone and limestone, D and E, are thirty feet long, and the sketch is taken from ledges on the telegraph road in Highgate, one mile west of Mr. Haflin's stone house. The evidence in favor of the unconformable position of these rocks is not so clear as we could wish, yet it seems to agree with the position of things at Highgate Falls, two or three miles south.

"Do not these facts show that after the slates had been formed and elevated at a small angle, the Oneida Group was deposited upon their edges, entirely concealing both the Utica and Hudson River slates east of Highgate Springs? and that in the alluvial period the Oneida grit was worn through at the locality of Fig. 247, thereby revealing the slates? The slates also appear to the east of the grits [Georgia slate.]

"Two additional facts confirm this view:

"1. The Oneida grits at Highgate Falls occupy a depression in the slates. There seems to be a depression like a trough, excavated from the edges of the slates, in which the grits were subsequently deposited. It is unusual for the slates elsewhere to occupy the higher place, because they decompose more readily than the tough sandstones and breccias. The higher position of the slates may be seen upon the north branch of the Missisco River, not a great distance from the village of Highgate Falls.

"2. The elevation of the slates was caused by the formation of the great anticlinal axis which separates the eastern and western Palæozoic barriers of North America from each other. This elevation probably took place near the close of the Hudson River period. As the lower silurian limestones experienced great lateral pressure during this disturbance, they were plicated (as is shown in the Trenton limestones at Highgate Springs, in Fig. 181.) The same force must have affected the slates overlying the limestones, though they may not have been so much disturbed. They might simply be tilted up at a small angle, so that the rock next formed would rest upon its edges discordantly.

"If this unconformability be admitted, it simply adds to our previous knowledge, the fact of the existence of discordant stratification between the Hudson River Group and the upper silurian in a new locality. The Canada geologists have described a similar unconformability of these same rocks as they extend to Gaspe, near the mouth of the River St. Lawrence.

"Following the grits and slates southerly in Vermont, the greater inclination of the Hudson River slates than the overlying sandstones is nearly constant. For instance, at

St. Albans Bay the slates dip 30° E., near the line of junction (though at St. Albans Point the dip is only 5° E.), while the Oneida dips from 5°–10° E. At Milton the slate dips 12° S. E., and the red dolomite dips 10° E. At Charlotte the slates dip about 30° E. in many places, while the dip of the sandstone is much less, say 12° E. At Snake Mountain the slates dip to the east 15° more than the sandstone. These facts tend to the conclusion that perhaps this unconformability may be traced over a wide area."

QUARTZ ROCK.

SYNONYMS.

QUARTZ ROCK: *Professor Chester Dewey's Geological Map of a part of Massachusetts, etc.; American Journal of Science and Art*, I. Series, Vol. VIII; 1824.

QUARTZ ROCK: *Geological Report of Massachusetts*, 1832; *by Professor Edward Hitchcock.*

GRANULAR QUARTZ, AT THE BASE OF THE TACONIC SYSTEM; *Professor E. Emmons' Works on the Taconic System;* 1840, 1860.

POTSDAM SANDSTONE: *Professors H. D. and W. B. Rogers, Proceedings of the American Philosophical Society;* 1841.

POTSDAM SANDSTONE: *Geology of the First District of New York*, pp. 439, 440; *by Professor W. W. Mather;* 1843.

QUARTZ ROCK, PERHAPS POTSDAM SANDSTONE: *Third Annual Report on the Geology of Vermont*, p. 13; *by Professor C. B. Adams;* 1847.

POTSDAM SANDSTONE: *Palæontology of New York*, Vol. I; *by Professor James Hall;* 1847.

Lithological Characters.

The general character of this formation is that of compact semi-vitreous sandstone. The varieties of this species, and the associated rocks, are the following:

1. Semi-vitreous, very compact, quartz rock.
2. Granular gray, or reddish, quartz rock.
3. Fine granular, or arenaceous, quartz rock.
4. Granular porous quartz, or Pseudo-Buhrstone.
5. Quartzose aggregate.
6. Talcose and mica schists.
7. Quartzose breccia.
8. Quartzose and micaceous conglomerates.
9. Limestone.

The term quartz rock, or quartzite, as it is sometimes called, may embrace several minerals in its composition, at times, provided that quartz is the most abundant constituent. In Vermont the term is applied principally to that great range at the west foot of the Green Mountains, which forms a high mountain range between Pownal and Starksboro. The greater part of it is a semi-vitreous or hyaline quartz, remarkably compact, and seemingly a sandstone partially metamorphosed. This variety is traversed by numerous joints, parallel to one another, and generally so near one another as to be mistaken for planes of stratification, even by the most experienced eyes. The texture is often as fine as that of the pencil slates of Rutland County; one homogeneous mass. It is remarkably compact and enduring. Bowlders of it may be found all over the southern part of the State; even three feet in diameter fifty miles from the parent ledge. Along the range of this rock these bowlders cover the surface, making tillage almost out of the question; and they have received the appropriate provincial name of "*hard-heads.*" Any one who has traveled much upon them finds his rate of progress most seriously impeded, and realizes most fully the fact that they are exceedingly compact. For removing large masses of this variety, the only practicable method is to build large fires upon them. The heat causes flakes of the stone to separate from the mass in angular fragments, and at the same time the mass is rendered brilliantly red from a change in the combination of the iron.

Every general section crossing the formation encounters this variety. For localities where it is developed better than usual, we refer to East Bennington, Sunderland, East Dorset, Peru, Goshen, Middlebury, Bristol and Starksboro. It is very difficult to decide whether a mass of hyaline quartz in the southeast part of Monkton belongs to the quartz rock or the red sandrock series. Specimens of this variety in the Cabinet are white, red, gray, salmon-colored, and every intermediate shade.

So much of this rock is granular, that Prof. Emmons has named it *Granular quartz.* By this term, employed to denote the second variety, we mean a coarser gray or reddish compact granular quartz, or sometimes a sandstone. It is what Potsdam sandstone would become if it were rendered a little more compact. This variety is more distinctly stratified than the preceding. We include under it a schistose variety (whose marks of stratification, as recorded, no one will doubt), having often laminæ of the eighth of an inch in thickness between the strata. We also include under the term granular quartz, all other varieties of rock, purely quartz, not included in the first and third specifications. These varieties occur upon every section as before, but are best seen in Pownal, Peru, Winhall, Tinmouth, Clarendon, Wallingford, Rutland, and the east part of Bristol. Upon the deposit extending from Rutland to Danby there are several peculiar quartzose varieties associated with it.

The third variety specified is a fine sandstone or arenaceous quartz rock, closely resembling the unaltered Potsdam sandstone. For some cause this variety decomposes very readily, thereby originating the *glass sand*, so valuable for economical purposes. It is most abundant in Bennington, Shaftsbury, Arlington, Dorset and Monkton.

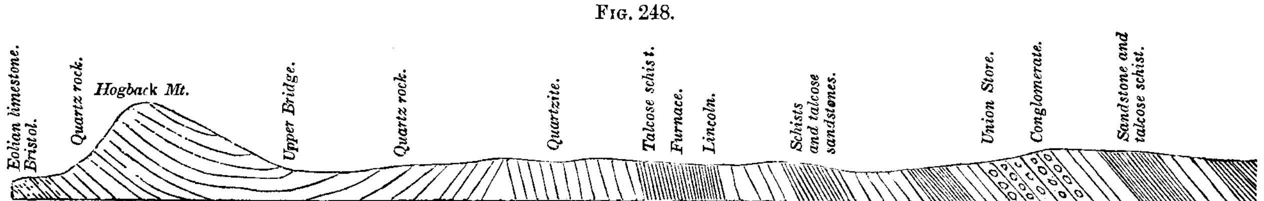
The fourth variety was first described in the Geological Report of Massachusetts, and is not always associated there with this formation. It resembled the French buhrstone, which is used for millstones, and was ascertained to be a variety of gneiss, whose feldspar had decomposed and disappeared, leaving the quartz full of cavities. We have noticed that certain rocks, which might be described in the same language, are very abundant among the bowlders of quartz rock at the foot of the Green Mountains. Sometimes the feldspar has not decomposed, in fact in Vermont this is generally the case. So numerous were blocks of this description in Bennington, that formerly all the feldspar used in the Pottery Works was obtained by crushing these bowlders, and separating from the fragments the crystals of this mineral. In the conglomerate at East Wallingford feldspar is a large ingredient. It seems often to have been formed by the alteration of the rock; crystallizing while the mass was plastic. We regret that we have no analysis of the different varieties of quartz rock, in order to ascertain how many of them contain besides alumina and alkalies, silica, sufficient to produce crystals of feldspar or other minerals; and whether the mica and talcose schists associated with the quartz rock could have been altered from the pure quartz, with perhaps the aid of rather more than the usual amount of reagents, dissolved in the water of the period of their production.

The *quartzose aggregate* is a difficult rock to name. It is homogeneous, of a dark gray color, and appears to be mostly composed of silica. It slightly resembles novaculite, but is an entirely different rock. The typical specimens (No. $\frac{3}{55}$, in the Cabinet) are from Sunderland, near the junction of the quartz rock and Stamford granite. In Pittsford and Brandon, there is a great abundance of the same variety. A similar rock is abundant in the red sandrock series. Careful analysis of these specimens will determine their exact nature.

The talcose schists are in a belt of rock extending from Starksboro to Ripton, with perhaps repetitions. There is an excess of silica in it, and probably they contain as little magnesia as the analyzed specimens from the great talcose schist formation east of the Green Mountains. The mica schist (mica and much quartz) is abundant in Brandon, Goshen, Mendon and Ripton. The specimens are the most characteristic in the first two localities upon Section VIII. It is a singular fact that a pure quartz rock, of such marked characters as the first variety, should be interstratified with so many entirely different rocks. A more extended account of these interstratifications, as well as of the formation in general, may be found in the detailed account of the first seven sections.

To illustrate these varieties we introduce a section of the rocks between Bristol and Lincoln (Fig. 248.) The south end of Hog Back Range, east of Bristol village, terminates abruptly in a precipice four hundred feet high. It is composed of rather coarse, very

Fig. 248.



Section from Bristol to Lincoln.

compact quartz rock, and its strata are beautifully shown, dipping to the east at an angle of 40°, gradually lessening to 28° E. In a distance of nearly two miles the synclinal axis is most distinctly exhibited. It is one of the prettiest synclinals in any rock in Vermont. Where the road to Lincoln crosses New Haven River (upper bridge), the strata dip 18° E. and are composed of quartz layers much waved, and separated by a micaceous or argillaceous film. In the extreme east part of Bristol, the quartz dips to the west, rising from 0° to 48°. Here the character changes to a quartzose rock, dipping east 75°. There seems to be no connection between these two rocks except by a fault; but we found no evidence of this except in the sudden change of position (in a few rods) with no intermediate ledges, and in the difference of lithological character. In the west part of Lincoln, at the Furnace, it is the ordinary talcose schist associated with this formation in other localities. At a Union store east of Lincoln village, the character

changes again to a distinct conglomerate of pebbles, varying in size from grains to small hens' eggs. What is most remarkable respecting this conglomerate, is that most of the pebbles are composed of blue hyaline quartz; the same pebbles that occur both in the red sandrock series and the quartz rock. The dip is about 50° E. The rocks extending beyond Lincoln village are generally talcose schists, associated with what appears like talcose sandstones, mostly altered into schists, and dipping 50° E. Nos. $\frac{8}{119}$ to $\frac{8}{133}$ illustrate this section in the Cabinet.*

The quartzose breccia consists of angular fragments of granular quartz, cemented by peroxyd of iron. In Massachusetts this variety occurs in large bowlders six or eight feet in diameter, in Great Barrington and Sheffield, having a cement of quartz instead of iron. We have seen it also in Vermont, particularly upon the first and second sections. We are quite sure that it occurs further north, but are unable to specify localities. Wherever it is abundant, it may be a profitable source for iron ore.

The coarse conglomerates are much more common, and are very interesting. They consist of a paste of quartz and mica, in which are imbedded numerous distinctly rounded pebbles of granular or hyaline quartz (No. $\frac{1}{84}$ in the Cabinet.) The pebbles vary in size from grains of sand to a foot in diameter. The situation of this deposit is invariably at the east side of the formation, and generally at its base, so far as we can judge. At every locality there is some variation in its character; hence we will describe the localities.

First, at Clarksburgh, Mass., two miles south of the Vermont line there is a deposit of conglomerate from which bowlders in western Mass. have been derived in great numbers, corresponding with the general description of the conglomerate. None of the pebbles are larger than hens' eggs. Specimen in the Cabinet No. $\frac{1}{84}$.

At Sunderland in Vermont the largest pebbles are about the size of small beans.—About half of them are composed of a beautiful blue hyaline quartz: the others are of a dull gray color. The contrast heightens the beauty of the specimens, and we think that when polished the rock might be useful for ornamental purposes. The locality is upon the hill at the eastern border of the formation on the Stratton turnpike (No. $\frac{3}{66}$.)

In Dorset and further north, bowlders of a similar conglomerate with large pebbles of the same blue quartz are common. We have not found it *in situ*; but the original ledge must be a few miles north of East Wallingford.

Upon the land of Nathan J. Smith, of Clarendon, in East Wallingford, about three-fourths of a mile north of David Hager's, is the finest locality of this pudding stone that we have seen. The out crop is half a mile long and twenty rods wide, running north and south dipping 70°W. Hence the thickness of the conglomerate is at least 200 feet. The conglomerate is composed of a paste of talcose matter or sandstone in which there are many crystals of feldspar, containing the large and small pebbles imbedded in it. The pebbles are mostly of an oval shape, having the longer diameter coinciding with the line of strike. Others are drawn out at great length, by a process explained in our First Part (specimens in the Cabinet Nos. $\frac{5}{187}$ to $\frac{5}{191}$.)

The conglomerate is interstratified with cuneiform-shaped beds of talcose schist, both varieties insensibly passing into each other. This schist differs but little from the so called

* The rocks east of the fault are now considered as forming a distinct group of strata, and are elsewhere described as talcose conglomerates.

gneiss immediately east. The beds of the conglomerate vary from one to ten feet in thickness—those of the green schists never exceed three feet. A system of east and west joints crosses the ledges, cutting the pebbles in two as well as the rock itself; the face of the joints is smooth as may be seen in specimens, a few of which have been obtained.—Single pebbles may be divided in the middle by some of these joints. The subject of the elongation of the pebbles and their division is of great importance to our theoretical knowledge, and is therefore fully treated in Part I.

North of Wallingford bowlders of coarse sandstone are occasionally seen, as in the north part of Rutland, which probably are from the same layer. Upon the west side of Bald Peak, at Grangerville in Pittsford, there is a very coarse conglomerate associated with quartz rock. The pebbles are often several feet in diameter, and are mostly composed of quartz.

Although the formation has always been regarded as purely silicious, a large amount of limestone is associated with it; whether as integral constituents or the result of plication is not positively settled, though the probabilities are in favor of the former supposition.—In Shaftsbury, west of E. Stone's house in the northeast part of the town, there is considerable limestone, and we should not be surprised to learn that it extended to Bennington along Furnace Boook. There is an extensive bed of limestone in Mendon, near the quartz rock, whose connections have not been traced out. At Goshen there is a north and south valley in the midst of the quartz rock, in which lime is said to exist: but we have made no search for it. It is not unlikely that a small amount may be found there. At Lake Dunmore there is a considerable width of silicious limestone west of the lake, between two ledges of quartz rock, all dipping east. The quartz rock is semi-vitreous near the lake, thus showing a considerable degree of metamorphosis. The west edge of the quartz rock and the east edge of the great range of crystalline limestone is a mongrel calcareo-silicious rock approaching in character the peculiar mixed rocks of the Red Sandrock Series.

It is likely that this band of limestone continues into Bristol, for in the valley of the north branch of New Haven River, passing up to Starksboro, there are ledges of limestone occasionally seen, interstratified with the quartz, nearly as far as Starksboro Village, and there is reason to suppose that it may extend to meet a narrow belt of limestone running south from Hinesburgh. The valley running from Hinesburgh to Bristol east of Hog Back Mountain is apparently formed principally by the softer nature of the rock — the limestone — situated in it.

A narrow strip of impure limestone partially separates the quartz rock from the red sandrock in Monkton. The limestone gradually thins out and is finally lost, so that the quartz rock and red sandrock unite with each other; and probably the line of junction is only a line separating different degrees of metamorphic action upon the same formation.

Divisional Planes.

Joints and a structure allied to cleavage are very common in this formation, though our recorded observations are meager.

Locality.	*Strike.*	*Dip.*	*Observer.*
Sunderland,	N. 25° E.,	90°,	C. H. H.
Sunderland, crossing do.,	E. and W.,	74° W.,	C. H. H.
East Wallingford,	E. and W.,	90°,	C. H. H.
Tinmouth, southeast corner,		90°,	A. D. H.
Ripton, near center,	N. 5° E.,	69° W.,	C. H. H.
Ripton, near center,	N. 12° W.,	35° E.,	C. H. H.
East Middlebury,	N. 70° E.,	90°,	C. H. W.

The two cases from Sunderland and those from Ripton are examples of the structure referred to as so much like cleavage. The rock is white, homogeneous, and the planes are about the same distance apart as planes of stratification. Wherever different sets of joints are found upon the same ledge, the rock is divided into rhomboidal and various shaped masses, always having smooth surfaces.

DIP AND STRIKE OF THE STRATA.

Locality.	*Strike.*	*Dip.*	*Observer.*
Pownal, east part,		25° E.,	C. H. H.
Clarksburgh, Mass., top of Oak Hill,		10° W.,	C. H. H.
Clarksburgh, Mass., Oak Hill,	N. 45° W.,	25° S.W.,	C. H. H.
Bennington, east part,	N. and S.,	18° E.,	C. B. A.
Bennington, east line,	N. and S.,	10° E.,	C. H. H.
Sunderland,		20° W.,	C. H. H.
Sunderland, west part,	East of north,	10° W.,	C. H. H.
East Arlington,	N. 45° E.,	20° S.E.,	C. H. H.
Winhall, northwest part,	About N. and S.,	3° E.,	C. B. A. and A. D. H.
Winhall, northwest part,	About N. and S.,	4°–5° W.,	C. H. H.
West Peru,		0°–4° E.,	C. H. H.
East Dorset, town line,		About 20° E.,	E. H.
Wallingford, North, one mile east of,	N. 20° W.,	20° E.,	C. H. H.
Wallingford, west part,		Nearly horizontal,	C. H. H.
Wallingford, east part, west of conglomerate,	N. 10° E.,	74° W.,	C. H. H.
Wallingford, east part,	N. and S.,	65°–80° W.,	A. D. H.
Wallingford, east part,		Dip east, and 90°,	C. H. H.
Wallingford, white rocks,	N. 10° E.,	60° W.,	A. D. H. and C. H. H.
Mendon,		Dip east, (?)	C. H. H.
Danby, north part,		Dip east,	C. H. H.
Danby, north part,	N. 30° E., to E. & W.,	0°–60° N. and N.E.,	C. H. H.
Tinmouth, west of the Pond,	N. 20° E.,	90°, and 80° W.,	C. H. H.
Tinmouth, southeast corner,	N. 20° E.	90°, (?)	A. D. H. and C. H. H.
Tinmouth east part,	N. 20° E.,		A. D. H.
Tinmouth, middle of east part,	N. 20° E.,	48° E.,	A. D. H.
Tinmouth, east part,	N. 20° E.,	58° E.,	A. D. H.
Tinmouth, northeast part,	N. 20° E.,	50° E., in two places,	A. D. H.
Tinmouth, northeast corner,	N. 20° E.,	50° E.,	A. D. H.
Bennington, Scolithus locality,	N. 60° W.,	10° S.W.,	A. D. H.
Bennington, north part,	N. 20° E.,	10° E.,	A. D. H.
Shaftsbury, north part,		Dip W., and E. also,	A. D. H.
Manchester, east part,	N. 25° E.,	30° E.,	C. H. H.
Wallingford, east part,	N. 18° E.,	90°,	E. H., jr.
Clarendon, west of center,	N. 45° W.,	35° N.E.,	A. D. H. and C. H. H.
Clarendon, west of center, on hill,	N. 20° E.,	86° E. to 90°, & 85° W.,	A. D. H. and C. H. H.
Clarendon, just west,	N. 20° E.,	90°,	A. D. H. and C. H. H.
Clarendon, north part,	N. and S.,	12° E.,	A. D. H.
Clarendon, north part,	N. and S.,	10° E.,	A. D. H.
Rutland, south line,	N. 10° W.,	37° E.,	C. H. H.

Rutland, south line,	N. 10° W.,	60° E.,	C. H. H.
Rutland, "Center,"	Variable, E. of N.,	13° E.,	C. H. H.
Rutland, north of center,		Dip east,	C. H. H.
Rutland, north part,	East of north,	8°–10° E.,	C. H. H.
Rutland, northeast part,	N. 20° E.,	10°–12° E.,	C. H. H.
Rutland, on Pittsford line,	N. 10° E.,	Dip east,	E. H., jr.
Mendon, near post-office,		55° E.,	C. H. H.
Pittsford, southeast part,		40° W.,	C. H. H.
Pittsford, west foot of Bald Mountain,	N. 60° W.,	45° W.,	C. H. H.
Pittsford, top of Bald Mountain,	N. 60° E.,		C. H. H.
Pittsford, near village,	N. and S.,	50° E.,	C. B. A.
Pittsford, half mile east of Furnace, in Furnace R.,	N. 45° W.,	45° S.W.,	C. H. H.
Pittsford, near north line,	N. 10° E.,	55° E.,	C. H. H.
Chittenden, west of the cave,	N. 10° E.,	56° E.,	C. H. H.
Chittenden, northwest part,	N. and S.,	65° E.,	C. B. A.
Brandon, northeast part,	N. and S.,	60° E.,	C. B. A.
Brandon, northeast part,	N. 5° E.,	70° E.,	C. H. H.
Brandon, northeast part,	N. 5° E.,	75° E. to 60° E.,	C. H. H.
Goshen, west part,	N. 5° E.,	60° E.,	C. H. H.
Salisbury, east side of Dunmore,	N. and S.,	65° W.,	C. B. A.
Salisbury, west side of Dunmore,		About 60° E.,	C. H. H.
East Middlebury, Furnace,	N. 55° E.,	10° E.,	C. A. W.
East Middlebury,	N. 20° E.,	50°–70° E.,	C. H. H.
East Middlebury,	N. 20° E.,	80° E.,	A. D. H. and C. H. H.
East Middlebury,	N. 20° E.,	East,	A. D. H. and C. H. H.
East Middlebury,	N. 5° E.,	85° W.,	A. D. H. and C. H. H.
East Middlebury,	East of north,	East,	A. D. H. and C. H. H.
Ripton, west line,	N. 20° E.,	90°,	A. D .H. and C. H. H.
Ripton, west part,	N. 20° E.,	90°,	A. D .H. and C. H. H.
Ripton, west part,	N. 19° E.,	80° E.,	A. D. H. and C. H. H.
Ripton, west of village,	N. 12° E.,	35° E.,	A. D. H. and C. H. H.
Ripton, west of village,	N. 5° W.,	69° W., (?)	C. H. H.
Ripton, at village,	N. 10° E.,	34° E.,	A. D. H. and C. H. H.
Lincoln, west line,	N. and S.,	48°–50° W.,	C. H. H.
Bristol, east line,	N. and S.,	20° W.,	C. B. A.
Bristol, east part,	N. and S.,	50° W., to 0°,	C. H. H.
Bristol, east part, bridge,	N. 12° W.,	18° E.,	C. B. A. and C. H. H.
Bristol,	N. 35° E.,	0°–50° E.,	C. H. H.
Bristol, north line,	N. and S.,	80° W.,	C. B. A.
Bristol, north line,	N. and S.,	65° W.,	C. B. A.
Starksboro, south part,	N. and S.,	80° W.,	C. B. A.
Starksboro, north part,	N. and S.,	90°,	C. B. A.
North Starksboro village,	N. 10° E.,	25° E.–90°,	C. H. H.
Woodford, southwest part,	N. 51° E.,	60° S.E.,	C. H. H.
Woodford, southwest part,	N. 75° E.,	38° S.,	C. H. H.

It requires in many cases careful attention to discern planes of stratification in the purely granular quartz of Vermont. Generally they are present, and exhibit great distinctness and regularity of stratification, particularly the variety containing mica. When the mica is in small quantity, the thickness of the strata is considerable; but as the mica increases, the layers are thinner, until at length the rock becomes schistose.

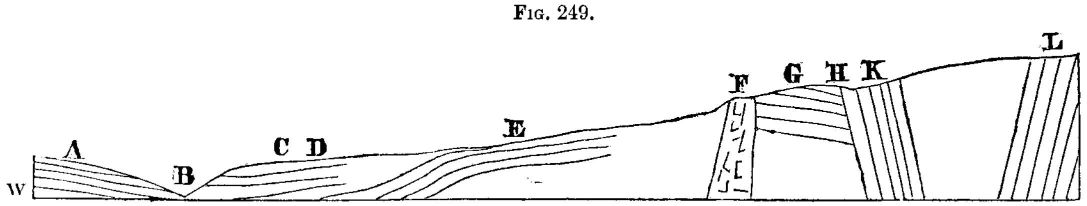
In general the strike of the ledges corresponds to the strike of the formation, as well as to the adjoining rocks. The question whether the quartz rock is interstratified with the Eolian limestone beneath and gneiss

above, has generally been answered in the affirmative. There is little doubt of its stratigraphical relations to the former, as in most of our sections it is seen to overlie the Eolian limestone, or else, as in the deposit running south from Rutland, interstratified with it. Let us present in a tabular form the relations of the quartz rock and gneiss to each other:

Locality.	*Position of Quartz rock.*	*Position of Gneiss.*
Massachusetts,	A synclinal trough—most of the strata dip east,	Granite underlying the quartz.
Section I,	Probably the same,	Granite underlying the quartz.
S. W. Woodford,	All that is seen dips east (Fig. 251),	Unknown.
Section II,	All at a small angle,	Perpendicular.
Section III,	A perfect synclinal basin,	Granite veins at junction, gneiss near, dips E. 60°.
Section IV,	A synclinal basin,	Dip west beneath quartz.
Section V,	Synclinal basin, E. side dip 70° W., W. about 50° E.,	Perpendicular or high dip to east.
Section VI,	Uncertain. Probably both dip east.	
Section VII,	Both dip east,	Overlies quartz.
Section VIII,	Variable,	Overlies quartz.
Bristol,	A perfect synclinal basin (Fig. 248),	Uncertain.
Starksboro,	Position uncertain,	Both perpendicular at their junction.

Upon Section III. the quartz rock is slightly disturbed at the junction. The gneiss is highly inclined and appears to underlie the quartz. Fig. 249 shows the particulars.

FIG. 249.



Section in Sunderland.

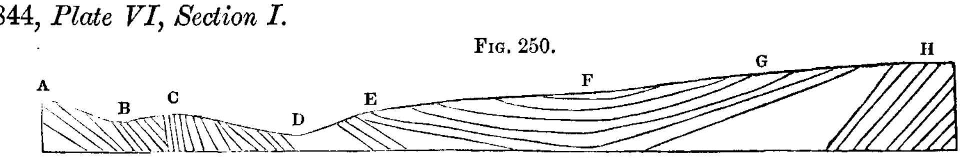
Explanation of Fig. 249.

A Quartz Rock, dip 20° E.
B Stream.
C Quartz rock, N. 45° W., dip 10° W.
D Locality of *Scolithus linearis* (Hall.)
E Gneissoid quartz, dipping 15° W. at first, but increasing to 25°.
F Granite like that in Stamford.
G Quartzose rock, dipping 10° E.
H A slide or fault.
K Gneiss, N. and S., dip 60° E.
L Gneiss, high dip to the west.

The land rises rapidly from L to the top of Stratton Mountain.

Prof. Emmons terminates one of his New York sections at Sunderland, and upon it has represented the quartz rock as nearly horizontal resting upon highly inclined strata of gneiss. See his *Taconic System, Albany*, 1844, *Plate VI, Section I.*

FIG. 250.



Section in East Dorset and West Peru.

Explanation of Fig. 250.

A Eolian limestone at the foot of Mount Eolus.
B Western Vermont Railroad Station at East Dorset.
C Nearly vertical strata of Eolian limestone.
D Valley. Rocks obscured by drift and tertiary deposits.
E Micaceous quartz rock, dip 10° E.
F Hyaline quartz rock, horizontal.
G Micaceous quartz rock, dip 20° W.
H Gneiss, dip 50° W. at Wood & Brown's saw-mill, in Peru.

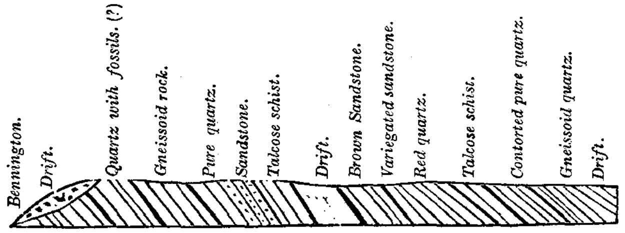
This section is in the valley of Mad Tom Brook. This figure represents the position of the quartz rock much better than Section IV. This is one of the clearest sections across this rock, that we have seen in the State. Yet there are other sections, where the strata all dip in one direction, and the quartz beneath the gneiss, so that we are perplexed to understand the true relation of the two rocks to each other.

Under the present head we only present the facts respecting the position of this formation, reserving the conclusions to be drawn from it for the last topic.

Range, Extent and Thickness.

The range and extent of this rock are quite simple. A band, never more than three miles wide, enters the State in Pownal and takes a northerly course with minor curves, until it reaches Starksboro, where it terminates. There is a smaller deposit, perhaps connected with the principal one, leaving it at Pittsford, and extending southwesterly to Danby.

Fig. 251.



Section of Quartz rock in Woodford.

Fig. 251 represents the position and character of this rock, in the southwest part of Woodford, on the old turnpike road from Bennington to Hartwellville. It is nearly two miles long. No rocks are seen on this road, going east from Bennington, till the "elbow" is reached. There the first specification is found, the supposed fossils being cavities in the rock, one-sixteenth of an inch in diameter, and cylindrical, filled with ferruginous decomposed matter. An obscure vein of the Stamford granite was found in one of the ledges. Were these abundant, we should have full evidence that the granite was formed subsequently to the quartz. It is probable that before reaching the granite, the quartz rock dips east, as in Clarksburgh, Mass. A few miles southeast of this section (Fig. 251), drift covers the surface for at least two miles.

If a thorough exploration could be made of the wilderness in the north and west parts of Stamford, and the south part of Woodford, much of the obscurity which now perplexes us might be removed. And yet it may be that the drift accumulations are so abundant as to forbid the discovery of any ledges. This perplexed us in the central parts of Woodford. The quartz rock continues north, forming the highest parts of the Green Mountains, in the south part of the State. Mount Prospect, in the southwest part of Woodford, is 2690, and Bald Mountain in the northeast part of Bennington, is 3124 feet above the ocean. The formation thus bends a little to the northwest, in passing from Woodford to Bennington. It even extends half way through the north part of the town, and is quarried for building purposes, upon the land of Gen. Harwood. The west line of the quartz rock is irregular through Shaftsbury. In the southeast part of the town it has decomposed, but in such a way that the resultant white glass sand contains most beautiful specimens of the *Scolithus linearis*.

Cobble Hill is composed of jointed quartz rock. The high range of mountains in the west part of Glastenbury is quartz, as its bald summits shining in the sun evidently testify.

The rocks of this formation in Sunderland are noticed in our remarks upon Section III. The most interesting particulars respecting the quartz rock in its whole course, are detailed in the descriptions of the general sections. We take pains not to repeat, under this head, what is described in those connections.

At Sunderland the quartz formation turns to the northeast, following the direction of the great valley. It lies mostly away from points accessible by roads. At a saw mill east of Factory Point in Manchester, east of A. Bourn's house, is seen the western limit of this rock, in ledges of semi-vitreous quartz much jointed. At the toll gate in Winhall, the rock is rather talcose in its appearance, lying in nearly horizontal layers. Following the quartz rock nearly due north, through Dorset, Mount Tabor, and Wallingford, we come to the "white rocks," a mountain composed of the first and second varieties of quartz; the strata dipping 70° W. on top of the mountain and about 30° W. at its base. The slope is too great to permit the growth of trees, and the mountain stands out distinctly to view, a naked rock, about 1,000 feet above Otter Creek. At its base are the famous ice-beds, among the debris of mammoth blocks that have fallen from the mountain, covering several acres. These blocks average four feet in diameter — the largest being twenty feet—and present a curious landscape in connection with the white rocks, a scene of magnificent desolation. Scarcely any plant except the leathery *Umbilicaria* can find a foothold upon the fragments. That is wonderfully prolific. Between the white and calico rocks, the eastern line of the quartz rock curves to the west, while that of the gneiss curves also, and in this series the gneiss is found at a much lower level than the quartz, which shows, we think, that the gneiss underlies the quartz rock, the overlying rock having been removed from this series by erosion. If erosion be denied,—though the valley of a considerable stream crosses the formation, and has been worn down by the stream between the white and calico rocks,—the fact of the curvature is sufficient to show that the gneiss was formed first, and that the quartz was deposited around the curve. The distance between the arc and the chord of this curve must be about a quarter of a mile.

The formation is mostly obscured by drift between East Wallingford and Chittenden, and more than an ordinary portion of it has been removed by erosion. Near Mendon Post Office, upon East Creek, the quartz rock, quite slaty, is exposed dipping 55° E.— Passing into Pittsford, there is a spur running from Blueberry Hill towards the second range of quartz rock in Rutland. The strata upon Blueberry Hill dip 40° W., as if it passed under the Eolian limestone. It is not quite certain but that this spur of quartz rock joins the smaller range and thus continues in a narrow belt to Danby, being associated during the southern part of its course with talcose schist.

The only point needing investigation is this: does the rock at Blueberry Hill connect with ledges in the northeast part of Rutland? There is a district about a mile in length that must be examined to answer this question. We have not ventured to connect them upon the map because it is a point of so much consequence in the theoretical geology of the State that we did not wish to state what had not actually been observed.

Quartz rock is abundant at two localities half a mile southwest of Blueberry Hill. Two miles from Blueberry hill it appears again, and in all these places it has its usual lithological character. A high hill separates East Creek from Otter Creek, upon which we were informed this rock existed. We certainly should expect to find it there, because it is found both north and south of it; and the superior hardness of the quartz, preventing decomposition, has preserved the hill from extinction. At a Mr. Griggs' house, north of Rutland Center and near Otter Creek, are rocks that belong to this belt of quartz. A quarter of a mile north of the Center, and at the Center itself, the real quartz rock is abundant. Passing south towards Clarendon the same rock appears near the town line. In the north part of Clarendon are several varieties of rock in the same range: brown quartz, talcose schist, gneissoid quartz, slaty quartz, all dipping to the east at a small angle.

In proceeding west from Clarendon Center, we cross over this range of quartz rock. On the eastern base of the high hill it dips 35° northeast, which is the usual position. The rock is a coarse quartz, and upon the crest of the hill it becomes slaty, dipping from 86° E. to perpendicular. Then a blue quartz appears, containing numerous veins of white quartz, which is succeeded by the common brown quartz, all of it being perpendicular. West of this is a silicious limestone of another formation. The hill continues south, increasing in height, into Tinmouth. Most of the formation in this town is of the common semi-vitreous variety: but in the southern part of the town it begins to be associated with slates of various kinds. These gradually increase in width until, in the north part of Danby, the quartz rock is entirely merged into them. These continue south till they are cut off by a fault from Danby Mountain.

This deposit of quartz rock in Rutland County, is represented in company with the adjoining rocks on Plate VIII, Fig. 2. It appears that its dips and strikes in different parts of the terrain do not agree with one another. At its southern terminus, small dislocations occur, making it dip to the north. It here (two miles north of Danby corners) resembles the coarser grit of the red sandrock. It is interstratified with the peculiar limestone of that series, and exhibits the same tendency to plication. In a distance of fifty feet there is a sharp synclinal axis, the east side dipping from 10° to 25° W. and the west side dipping 60° E.

Returning back to the principal range in Pittsford, we find that the relations of the quartz rock and Eolian (?) limestone are very complicated. Commencing at the spur in Rutland, the quartz rock passes into Pittsford, forming a high range of hills, of which Blueberry Hill, Spruce Hill, Long Hill, Bald Peak, and East Peak are parts. The dip of the strata in this range is generally to the east. The rock is hardly pure quartz, but rather the indescribable variety, designated as quartzose aggregate. Occasionally a coarse conglomerate shows itself. The eastern limit of this bend is west of South Chittenden. At Bald Peak the quartz rock runs N. 60° E., and in conformity with it the whole formation curves at this point and passes into Chittenden, upon the southeast side of Furnace River. The valley of the river is occupied mostly by limestone, though a short distance above Grangerville, half a mile above the Furnace, there is a limited amount of quartz rock, sandstone and conglomerate, running N. 40° W., and dipping 45° S.W., in the bed of the river. These ledges continue northeasterly, not increasing in width for three miles. Then the rock expands suddenly, and is represented upon the map as uniting with the curved range, from Bald Peak in the north part of Chittenden—though this is doubtful. At all events it is but a narrow band of limestone that separates the two quartz bands. In the north part of Chittenden there is a large amount of conglomerate.

There is a short range of talcose schist, mostly, which is colored as quartz rock, commencing near the Furnace, and passing a little east of north, near a small stream into Chittenden, and terminates near Chittenden Cave, near Nickwacket Mountain. Near its north end, its course is N. 10° E., and its inclination is 56° E. Its junction with the limestone east of it is perfect—the latter overlying the former. This range does not connect at either end with the principal range.

Two other long spurs of quartz rock terminate in Pittsford. The most eastern spur terminates in the south part of the principal village in Pittsford, upon Furnace Brook. One would think from an inspection of the map, that this spur must connect with the north end of the subordinate range in Rutland. The rock upon this spur is an indefinite kind of quartz rock, passing into conglomerate. Upon the east side of Sugar Hollow River, in the north part of Pittsford, the strata of conglomerate run N. 10° E. West of this range, in the limestone in the bed of the river, there is about fifty feet thickness of slate and conglomerate not connected with the principal range. The most western spur of all, terminates north of the Pittsford R. R. Station. It does not unite with the principal range, certainly south of Lake Dunmore. The relations of these different ranges of quartz rock and limestones to one another, in Pittsford, etc., need investigation. We have delineated upon the map, the facts so far as they are known; and a better idea of the numbers and shapes of the different spurs and ranges can be obtained by a hasty inspection of the map, than by many pages of particular description.

From Pittsford, the quartz rock, in several ranges, pursues a direct course for Forestdale in Brandon, on Section VII.

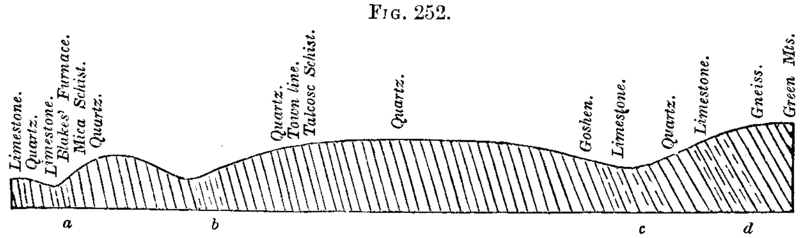
Lake Dunmore is in the west part of the formation. East of the water, the quartz rock rises abruptly into a mountain range. We are happy to be able to present a few words respecting its occurrence about the falls of the Lana, written by Rev. Augustus Wing, of Stockbridge, who visited the place at our request. The letter was addressed to C. H. Hitchcock:

"I went to the Falls of Lana, on the east side of Lake Dunmore, the day after leaving you. The brown quartz dips about 80° W. at the foot of the hill. A few rods east the semi-vitreous quartz occurs in great force, being in solid compact strata from ten to twenty feet thick, and standing nearly perpendicular. It is this mass of unusually compact rock that forms the principal barrier to the brook, and thus makes the falls. The stream is not as large as some others crossing the same range, in like manner, yet it was sufficient to drive a saw mill, as the remains of one still witness. The reason why the river has not entirely cut through the range, as it has at Bristol, East Middlebury, Brandon, and Rutland, is the occurrence of a greater amount of the semi-vitreous or hyaline quartz. At Bristol, you will recollect, in the gorge there was none whatever. At Brandon there are only two strata of it: one of them, two feet thick, was as true as a die across the brook, half a mile above Blake's furnace; the other is a short distance north. It was pointed out to me as a "curiosity." At East Middlebury the hyaline quartz I know is thirty or forty feet thick, and the stream has cut a deep passage through it under difficult circumstances: but that is of less account than the rock at the Falls of Lana.

"But I am forgetting the Falls. Suffice it to say, you ride a mile further than we did, walk another and you are at the stream hearing the noise of many waters above you. With curiosity excited, you hasten up the path, a steep shaded ascent for an eighth of a mile, and stand upon a precipice viewing the white waters foaming in an irregular narrow channel beneath some sixty feet. Next you wind down on the edge of the cliff to a circular basin at the foot of the falls. You go round under high projecting rocks, fearing they will fall, but know they will not, till you come round and up to the top of the falls. You step out upon the edge of a cliff of hyaline quartz and look down into the chasm one hundred feet deep — the waters are dashing at a furious rate. Presently the current takes a course at right angles with its general direction and follows the line of strike of the rock until it reaches the circular basin at the bottom of the fall. You gaze down around you on the wild war of the gallant stream —your head is a little unsteady — your nerves twinge — but soon you admire and become enthusiastic — you cry bravo! to the little brook, in its encounter, as it struggles and dashes down, to seek repose, with unconquered spirit, to the smooth lake below. Now you have seen the Falls of Lana. You return, but determine to visit them again."

The same gentleman has given us his views respecting the connection of beds of limestone with the quartz rock in Goshen and Brandon — conjecturing that they indicate several folds in the formation. The subject deserves a careful examination.

Fig. 252.



Section from Forestdale to Green Mountains.

"In going from Brandon to Rochester I went over the quartz on the road a little above Blake's Furnace at Forestdale, to the bed of limestone *a* in Fig. 252, on the *east* side of the quartz. This I found to be about twenty-five feet thick; and from it, by pacing, I found the thickness of the quartz rock east between *a* and *b*, not less than 900 feet thick. About half a mile further is the house of a Mr. Churchill, at the confluence of a stream from Leicester with Mill River in Brandon. As this valley corresponded with the position of the limestone east of the quartz at Blake's Furnace, I inquired of Mr. Churchill if there was any limerock up that brook. He assured me it was abundant, and that hundreds of tons of iron ore had formerly been dug in it—the ore occurring in "pots or pockets" and was different from the hematite on the west side of the quartz at Conant's bed. Mr. Churchill also said that in another valley running through Goshen, near Frank Brown's house, limestone, *c*, accompanied by iron ore, abounded; and that it extended south into Chittendon, connecting with Mitchell's ore bed in Chittenden. Not only so, but there was marble, *d*, further east still, on the Green Mountains, doubtless connecting with the marble in the north-east part of Mendon.

"Now you remember that we found the limestone of the west side of the quartz, folding around the north end of Hog Back Mountain and re-appearing at the east side in Starksboro. You remember too, we conjectured* the limestone might occur in the valley between Starksboro and Bristol, east of the quartz. We know that it occurs at Blake's east of the quartz, and up the Leicester Brook. Then why did it not once, if not now, occur all along in the east part of the quartz rock, as it is known to do on the west? And why may not the Frank Brown range of limestone in Goshen, and the Mitchell ore bed range in Chittenden, be of the same bed in another fold, or one interstratified in the same series? And if we call the quartz rock Potsdam sandstone, and the sandstones and limestones on the west calciferous sandrock, why not call the sandstones and limestones on the east calciferous sandrock also? If we may suppose the quartz rock of the Potsdam has been changed to hyaline quartz, why may we not suppose that the quartz rock of the calciferous sandrock has also become hyaline? And if we may make the hyaline quartz on the *west*, an indication of the limit of the calciferous sandrock, as it occurs at the Bristol ore bed, Monkton ore bed and 'putty bed,' and still further west in Monkton, why may we not make it the same on the east, as the hyaline quartz appears at Ripton Hollow, some two miles *east* of the quartz rock at East Middlebury?

"Now if these things are so, and if we may suppose a fault to exist between the Potsdam sandstone and the Hudson River Group on the east, must we not look for the supposed fault further east than the quartz

* This has subsequently been proved to be a fact. C. H. H.

rock? should we not look for it, if at all, certainly *east* of the limestones and sandstones, if they are like those on the west of the quartz rock?

"Another thing must be true also, if the quartz rock is the Potsdam, and the limestones and sandstones the calciferous: The limestones on each side of the anticlinal of the quartz rock will be more largely developed where they become united over the anticlinal, north of the sinking down and disappearance of the quartz rock. If the quartz rock is the Potsdam, I certainly shall expect a greater development of limestones in Starksboro and Hinesburgh. *You* have the facts to test this,—I have not, as I have not seen the rock directly north of the Hog Back range, up to and across the Winooski River. If the quartz rock is the Potsdam, that is the main anticlinal of the State."

This letter was written in Stockbridge, August 11, 1858.

The quartz rock, as it appears in Middlebury and Bristol, is described elsewhere. In East Middlebury, on the farm of George Sessions, there is a mass of quartz twenty rods long and fifty feet high. The mountain range of quartz continues unbroken, except at East Middlebury and Bristol. At the latter place the break is very noticeable, forming a marked feature in the scenery, and is seen for many miles around. The Green Mountains appear in the back ground rather higher than the quartz range, which is known in the vicinity as Hog Back Mountain. The village of Bristol is situated at the western base of the northern part of the range, and New Haven River flows through the gap. Whether this gorge has been excavated by the quiet action of the water alone without any fissure, is uncertain; but probabilities lead us to suppose that the quartz was removed, not by steady erosion so much as by the removal of the numerous jointed blocks of which the formation is full.

Much of the quartz rock in the valley between Bristol and Starksboro cannot be distinguished from members of the red sandrock series, and talcose schist is associated with it. A few fossils have been found near Rockville in brown quartz. The north part of this formation gradually tapers to a point; it is mostly semi-vitreous—the strata being discerned with great difficulty. It terminates in the north part of Starksboro, the point being enveloped in impure limestone.

One or two efforts have been made to ascertain the thickness of this formation. A favorable locality for this purpose, because of the horizontality of the layers, is in East Dorset; and by measurement the thickness was ascertained to be 973 feet. But as the top of the mountain is quartz rock, and as powerful agents of erosion have acted in the vicinity, we know not how much of the quartz has been removed. But it is proved that this formation is at least a thousand feet thick.

Prof. Emmons estimates its thickness in Clarksburgh and Williamstown, Mass., to be from 1070 to 1170 feet thick. It consists there in an ascending order of the following members: 1, millstone grit, 30 feet; 2, talcose schist, 70 feet; 3, sandstone, 100 feet; 4, talcose schist, 40 feet; 5, granular quartz, 400 feet; 6, quartz and silicious slate, 30 feet; 7, talcose schist, 400—500 feet thick.

Mineral Contents.

Very few minerals are found in this rock in Vermont. It is really a mineral by itself. The most important mineral contained in it is hematite, which occasionally occurs in small veins. Several beds of the brown hematite of tertiary age are located upon quartz rock, and may not unlikely be derived in part from these small veins.

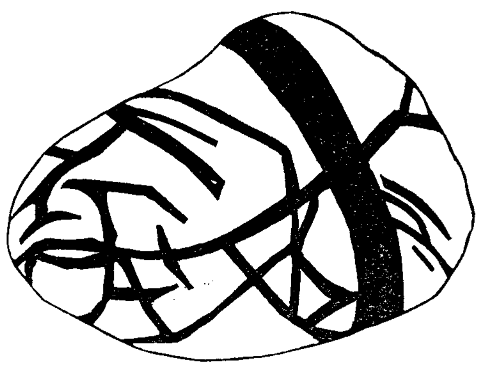
Iron pyrites are considerably common in small bright crystals. In the east part of Middlebury, high upon the Green Mountains, upon the land of Allen Foote, some strata have been discovered containing an unusually large proportion of crystals of magnetite — sufficiently numerous to be of considerable value in the vicinity of iron furnaces.

A small amount of plumbago is found in Chittenden and Brandon. Galena and copper pyrites are also ascribed to Brandon, and Prof. Thompson speaks of iolite in Chittenden.

Veins in Quartz rock.

Sometimes this rock contains veins of quartz scarcely separate from the base. They are usually white and opaque, and the rock a mixture of gray quartz and mica — the latter mineral existing, however, in very small proportion. Fig. 253 is a sketch of a bowlder about eight inches in diameter, which was originally from western Vermont, although it was picked up in Amherst, Mass. The principal part of it is gray quartz traversed by numerous veins of white quartz.

Fig. 253.



Veins in Quartz rock.

Organic Remains in the Quartz Rock.

Several species of fossils occur in the quartz rock. They are a species of *Lingula*, a mollusk resembling the *Modiolopsis*, a straight chambered shell (?), a few crinoidal columns, the *Scolithus linearis* (Hall), a few fucoids, and some indeterminable forms which are evidently organic.

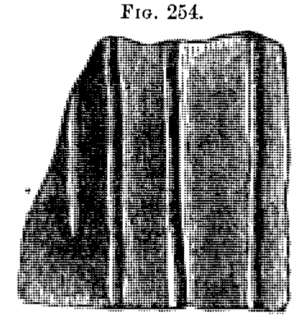
The Lingula is from the north part of the principal range of quartz rock in Starksboro, near Rockville, at the house of Mr. Hill. The locality was discovered by Henry Miles, of Monkton. The specimens contain scores of fossils, but none of them are very distinct. Prof. James Hall has examined them, and regards them as a new species of Lingula, related to a species contained in the Medina sandstone.

The "Modiolopsis," chambered shell, and encrinal remains are found in hyaline quartz on the west side of Lake Dunmore. The first and last were referred to the same authority by Prof. Adams. The following remarks concerning them we quote from *Foster* and *Whitney's Report upon the Land District of Lake Superior*, 1851, *Part II*, p. 205. "I have recently received from Prof. Adams, of Amherst, specimens of partially metamorphosed sandstone from Salisbury, Vermont, which he regards as the equivalent of the Potsdam sandstone. The specimens have all the characters of the purely quartzose variety of this rock, and contain fragments of crinoidal columns, and casts of an acephalous bivalve, similar to *Modiolopsis*.

"Such facts are highly interesting, and promise important results for the future. Since, however, no known fossils of the Potsdam sandstone occur with the rocks just mentioned, it requires a careful scrutiny to determine the age of the rock *in situ*."

The *Scolithus linearis* (Hall) is regarded by some as a plant, by others as a relic of an articulate animal. It generally presents the appearance of numerous linear stems, sometimes three feet long. The stems are generally numerous, and much resemble a series of small pins driven into the rock. Some authors have stated that the axis of this fossil is invariably at right angles with the position of the strata. If so, it may be of great service where it occurs in settling the position of the strata. It certainly would be in both of its localities in Vermont. The generic character of *Scolithus* is that of a stem, free, simple, cylindric or subcylindric, vermiform or linear, and never branched. The *S. linearis* has a simple rectilinear stem; its surface is nearly even, cylindric or compressed, and is sometimes apparently striated. Fig. 254 represents the *Scolithus linearis* from Vermont.

Fig. 254.



Scolithus linearis.

In the north part of Bennington, in Gen. Harwood's Quarry, there is a very fine locality of this species. The specimens are remarkably abundant and beautiful (Nos. $\frac{2}{84}$, $\frac{2}{85}$, in the Cabinet.) Where the rock has been altered or decomposed into glass sand, the Scolithus appears more distinct than usual. Beautiful specimens of the Scolithus in this decomposed rock occur at Harwood's Quarry. We have also seen much of this fossil in Sunderland, upon the route of Section III, (No. $\frac{3}{69}$, in the Cabinet.)

Many have considered this fossil as characteristic of the Potsdam sandstone. If this be so, then the age of the quartz rock is certainly known. It certainly has never been described from any other rock; but we do not feel authorized to accept the positiveness of its evidence, because (1) of its anomalous character; and (2) because it is found in a metamorphic rock, and may, therefore, have been altered from some species of organism, considerably different from the original of the Scolithus. For instance, upon the supposition that the quartz rock is middle silurian, we should imagine the *Fucoides verticalis* of the Oneida conglomerate would change into a form, not distinguishable from the *Scolithus linearis*.

We collected no specimens of the fucoids, which are quite common at the "upper bridge" in Bristol, though quite obscure. In the southwest part of Woodford, there seem to be traces of organism, resembling bivalve shells, about the size of a three cent piece. They are too obscure for recognition.

GEORGIA GROUP.

PRIMITIVE ARGILLACEOUS SLATE: *Prof. Chester Dewey's Geological map of Berkshire, Mass.; Columbia and Rensselaer Counties, N. Y.; American Journal of Science and Arts*, I. Series, Vol. VIII; 1824.

PRIMITIVE ARGILLACEOUS SLATE: *Geological Report of Massachusetts*, 1832.

BLACK SLATE AND TACONIC SLATE. ROOFING SLATE OF THE UPPER PART OF THE TACONIC SYSTEM: *Prof. E. Emmons' works on the Taconic System*, 1840 — 1860.

HUDSON RIVER GROUP OR LORRAINE SHALES: *Geological map of New York*, 1842; *also in the Palæontology of New York*, Vol. I; *by Prof. James Hall;* 1847.

"ROOFING SLATE OF THE TACONIC SYSTEM;" *but considered as of the Hudson River Group: Reports on the Geology of Vermont*, 1845 — 1847; *by Prof. C. B. Adams.*

UPPER PART OF THE HUDSON RIVER GROUP, OR A DISTINCT GROUP ABOVE THE HUDSON RIVER GROUP: *Quoted by Prof. James Hall, from the opinions of Sir William E. Logan; Twelfth Annual Report of the Regents of the University of the State of New York;* 1859.

UPPER HUDSON RIVER GROUP: *Elementary Geology*, 31*st edition*, p. 411; *by Edward Hitchcock, and C. H. Hitchcock*; 1860.

SLATES CONTAINING THE FIRST FAUNA, OR THE PRIMORDIAL ZONE OF LIFE: *Letter from M. Joachim Barrande to Prof. Bronn, of Heidelberg*, July 16, 1860.

BELONGING TO THE PRIMORDIAL ZONE OF LIFE, AND PERHAPS THE EQUIVALENT OF THE POTSDAM SANDSTONE: *Letter from Sir Wm. E. Logan to M. Joachim Barrande*, Jan. 3, 1861.

The rocks included under this head are distributed in two (perhaps three) terrains in Vermont, which are identified by their organic remains, viz., *Barrandia Thompsoni* (Hall), etc. The most northern terrain is found in Franklin and Chittenden Counties, extending probably from Quebec. The second terrain is seen first in Cornwall, in Addison County. From thence it gradually enlarges, and is several miles wide as it leaves Rutland County, and passes into New York. The third terrain, in which no fossils have been found, and is therefore not certainly of this age, is a band of clay slate, extending from Milton to Starksboro. Reasons are presented elsewhere for supposing that other bands of clay slate in the State may be of the same age.

We use the term *Georgia Group* to designate this terrain, from the town of Georgia in Franklin County, where it is developed in its full proportions, and where the most interesting fossils have been found. It is a name also which does not involve any theory, and may be used by both parties in the controversy respecting its age.

The name of *Georgia Group* or *Georgia slate* is given to this group of rocks rather than any other, such as *Fairhaven slate* or *Castleton slate*, because it is a purely geological designation, and has no reference to the economical value of the slate. Two reasons may be given for the preference of Georgia: 1. The whole of the group is developed in the town of Georgia, but is not in either of the others mentioned. It is a rule of geological nomenclature, that the whole series of rocks must be developed in the town, mountain, or along the river, from which the name is derived. 2. Nowhere but in Georgia, in Vermont, are the characteristic fossils of the group displayed. They have as yet been found only in the New York portion of the southern terrain. The geological character of the group is best developed in Georgia, and we are therefore compelled to use the name of this town in describing the slates geologically.

Lithological Characters.

The Georgia slate includes all the following varieties of rock:

1. Clay slate.
2. Roofing slate.
3. Clay slate, approximating to micaceous sandstone.
4. Various kinds of limestone.
5. Brecciated limestone.
6. Conglomerate, composed of pebbles of limestone.

The Georgia slate includes what Prof. Emmons has ranked as the black slate, Taconic slate, and roofing slate; and yet not altogether, for we have regarded all the black slate beneath the red sandrock as belonging to the Hudson River Group. The characteristic trilobites of the Georgia slate are represented by Emmons in his *Taconic System*, 1844, as found in the black slate. The color of this variety seems to be due to the presence of carbonaceous matter. The Taconic slate is described "as an even-bedded aluminous slate, varying from the finest possible grit to one that is coarse and rather uneven-bedded, and passing into a rock having many of the characteristics of a sandstone. We include both these varieties under the general term of clay slate, which is the most prominent member of the Georgia slate throughout the State.

The roofing slate, or that variety of clay slate which is sufficiently fine and compact to be used for roofing purposes, may be distinguished in general from the Hudson River slates in Vermont by the absence of any calcareous matter. Yet this is not an infallible character, because in the west part of Rutland County, and in a large part of Chittenden County, upon the third or eastern range of this slate, there is a small percentage of carbonate of lime present. This is noticeable in the slate at Hubbell's Falls at Essex Junction, where the rock may possibly have derived this element of its composition from an adjacent limerock. Some parts of the Hudson River slates, too, contain no carbonate of lime.

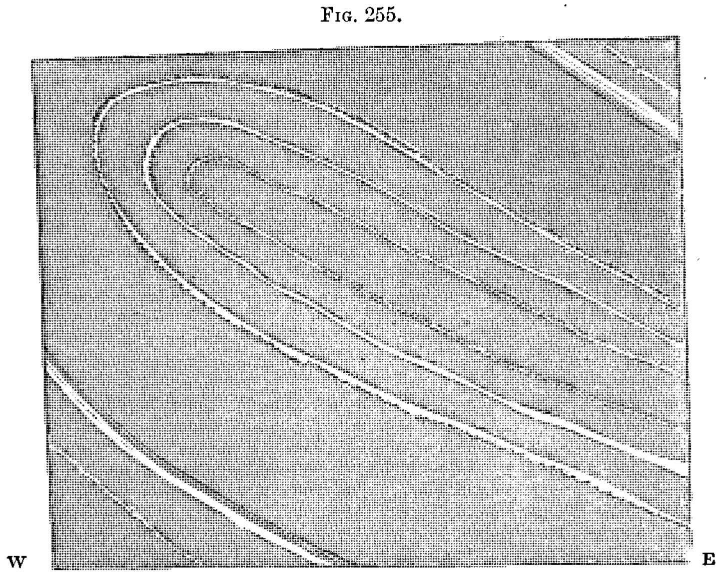
The finest roofing slates of the Georgia slate period in Vermont, are found in Rutland County. The excellent character of the slate for economical purposes is too well known to demand repetition here. It has various colors, such as greenish, reddish-brown, what is generally called "slate color," chocolate, mottled, bright red, bluish-gray. There are numerous shades of all these colors as well as innumerable intermediate varieties. Some of the varieties are so soft as to be used for slate pencils, and can be cut into every conceivable shape. Many of the layers are compacted together, and, being destitute of cleavage planes, appear like a thick homogeneous mass of argillaceous rock.

In Franklin County the clay slate of this series contains more silica than the same rock in Rutland County. It may be particularly noticed at the locality of the *Barrandia*, etc., in Georgia, where it is a black micaceous sandstone. It is micaceous also at St. Albans village, and changes into novaculite schist in the town of Franklin. The true clay slate seems to be developed in the east part of the terrain in the towns of Georgia and St. Albans. Distinct clay slate is also found further north.

Subordinate layers of rock associated with the clay slate in the southern terrain are the following: Coarse harsh sandstone with angular grains cemented together by a paste of chloritic aspect; beds of gray sandstone; green and black flinty slate; blue compact limestone; gray silicious limestone, and other limestones. In connection with the clay slate there are often numerous veins of a fetid whitish quartz, full of angular cavities, containing a brown residuum.

The layers of quartz rock and sandstone are quite thin, and are found chiefly near the upper part of the formation. In Rutland County the strata of quartz are interstratified with the roofing slates in thin bands of a few inches in thickness. Sometimes they enable us to ascertain the true planes of stratification in the slate, in distinction from the planes of cleavage.

Fig. 255.



Section at Barrett and Barnes' Quarry.

Fig. 255 represents layers of quartz interstratified with clay slate, in Barrett & Barnes' quarry on the west side of Lake Bombazine, in Castleton. The numerous fine lines in the figure represent the lines of cleavage, which generally coincide with the planes of stratification. The position of the layers of quartz is indicated by the ten spaces in the figure. These layers vary from one half of an inch to five inches in thickness. Were it not for these layers it would be impossible to distinguish the marks of stratification from the superinduced planes of cleavage. The strata makes a graceful inverted fold, dipping 39° east. This sketch was taken by Mr. Hager from the south end of the quarry. About eighty rods north of Barrett & Barnes' quarry, there is a similar curvature of slate and quartz layers; but the layers of quartz are thinner and fewer.

In Allen's north quarry in Fairhaven, the quartz layer is 6 feet thick. E. Hitchcock, jr. says that in all the quarries of roofing slate in this vicinity, numerous beds of granular and crystalline quartz, and also beds of limestone are found.

"From Highgate Falls to West Berkshire there are successive ranges of slate interstratified with quartz. This slate is of a light greenish hue, and appears somewhat chloritic."—*Z. Thompson.*

The beds of limestone associated with the clay slate are numerous and of varied forms. The largest belt is often two miles wide, and will be described under Eolian limestone.

Other large beds of limestone may be traced over many miles along the line of strike. In the southern terrain, the limestone is generally a bluish-brown compact rock containing considerable silica; and fetid when roughly fractured. When it is completely filled with white anastomosing veins of calcite or white quartz, it presents a beautiful appearance, and constitutes the rock called sparry limestone. It is often the same as the sparry limestone of the Taconic system, when it is quite thick. That term as used by Emmons is more extensive than we use it, for he includes under it all masses of limestone bounded on both sides by Taconic slate. By consulting the details of the first seven general sections a large number of beds of limestone will be found noticed.

Among the slate quarries in Rutland County the limestone occurs in numerous thin beds of several inches in thickness. It has nearly the same color as the slate, and must occasion some trouble to quarrymen in many localities.

The notes of E. Hitchcock, jr., give the following section of the West Castleton Railroad and Slate Company: Upon the top of the quarry there is

Taconic slate,	30 to 40 feet thick; and following it are
Sparry limestone, .	6 feet;
Green slate, . . .	6 feet;
Purple slate, . .	45 feet;
Green slate, . . .	6 feet;
Total,	118 feet.

William Hughes' quarry in Castleton, is overlaid by sparry limestone, often concretionary, and often interstratified with a decomposing slate.

Sometimes the beds of limestone, in the Georgia slate, are brecciated. There is one of this kind in Fairhaven (No. $\frac{6}{90}$, in the Cabinet); the fragments of which the breccia is composed are of a blue color, somewhat resembling the common variety of Trenton limestone. There are no fossils present to decide whether the fragments were derived from the Trenton or Eolian limestones.

The most peculiar rock associated with the Georgia slates, is a coarse conglomerate, composed of large pebbles and bowlders of limestone, imbedded in a calcareous cement. Often the cementing material is slaty, and the pebbles fuse, as it were, into the cement. We first find this variety in traveling north, near the north line of the town of Georgia, near William Caldwell's house. It is next seen at Mrs. Montifer's house near the north town line of St. Albans, a distance of four miles. It is not seen between these localities, because the rocks are covered up by the Champlain clays. The pebbles composing these strata contain a fossil, very much resembling the *Phytopsis tubulosum* of the Birdseye limestone.

About half a mile east of the village of Swanton, there is a boss of a peculiar bluish limestone, standing entirely alone in a plain, which is probably connected with this conglomerate, for at the village the conglomerate is prodigiously developed. It is, at all events, a variety of the Georgia slate formations. Following the road from Swanton to Highgate Falls, this conglomerate may be seen almost every rod of the way, as it forms a small ridge. Not only rounded pebbles, but large unrounded plates of a dark colored slaty limestone are abundant among the constituents of the conglomerate. Upon the supposition that the Georgia slate is presilurian, we cannot imagine from what rock these fragments were derived.

We left this range of conglomerate about three-fourths of a mile south of Highgate Falls, and cannot say how far it continues to the north. Its strike carries it about half a mile east of the Falls. The greatest superficial width covered by this conglomerate in any one locality, we should estimate at twenty rods.

DIVISIONAL PLANES IN THE GEORGIA SLATE.

We have noted the following observations respecting the position of superinduced structural planes of division in the Georgia slate:

Locality.	*Strike.*	*Dip of Cleavage Planes.*	*Observer.*
Fairhaven, east of Myers & Utter's quarry,	N. 40° W.,		E. H., jr.
North of do.,		40° E.,	E. H., jr.
Fairhaven, Williams & Tillson's,		About 80° E.,	E. H., jr.
Fairhaven, Allen's south quarry,	N. 70° E.,		E. H., jr.
Fairhaven, Eagle Slate Co.,	N. and S.,	60° E.,	E. H., jr.
Fairhaven, Eagle Slate Co.,	N. 80° E.,		E. H., jr.
West Castleton Railroad and Slate Co.'s quarry,	E. and W.,	70° S.,	E. H., jr.
Castleton, Barrett & Barnes,		30° E.,	A. D. H.
D. Hooker's quarry,	N. 20° E.,	27° E.,	A. D. H.
Castleton, Wm. Hughes',	N. 20° E.,	17° E.,	A. D. H.
Eagle Slate Co.,	N. 10° E.,	17° E.,	A. D. H.
Castleton, Hydeville Co.,		30° E.,	A. D. H.
Allen & Cooper's quarry,	N. 20° E.,	20° E.,	A. D. H.
Hughes' quarry,	N. 30° E.,	32° E.,	A. D. H.
Cornwall, north of center,	N. 10° E.,	90°,	C. H. H.
Georgia, south part,	N. 38° E.,	90°,	C. H. H.

STRIKE AND DIP OF THE STRATA.

SOUTHERN TERRAIN, PRINCIPALLY IN RUTLAND COUNTY.

Locality.	*Strike.*	*Cleavage.*	*Dip.*	*Observer.*
Hoosac Falls, N. Y.,	N. 45° E.,		55° S.E.,	C. H. H.
Shushan, N. Y.,	N. 30° E.,		30° E., 50° E., 20° E.,	C. H. H.
Rupert Village,	N. 15° E.,		55° E.,	C. H. H. and E. H., jr.
Poultney, south part,	N. and S.,		25° E.,	A. D. H.
Poultney, south part,	N. and S.,		40° E.,	A. D. H.
East Poultney,	N. 20° E.,		60° E.,	A. D. H.
Poultney, middle part,	N. 20° E.,		55° E.,	A. D. H.
Poultney, north part,	N. 20° E ,		55° E.,	A. D. H.
Poultney, Eagle Co.,	N. 10° E.,	17° E.,	20° E.,	A. D. H.
Poultney, Hooker's quarry,	N. 20° E.,	27° E.,	24° E.,'	A. D. H.
Poultney, Hughes' quarry,	N. 20° E.,	17° E.,	20° E.,	A. D. H.
Castleton, Hydeville Co.,			20°–40° E.,	A. D. H.
Castleton, Barrett & Barnes,		See Fig. 256, curvature,		A. D. H.
Castleton, Allen & Cooper,	N. 20° E.,	20° E.,	15° E.,	A. D. H.
Castleton, Hughes' quarry,	N. 30° E.,	32° E.,	36° E.,	A. D. H.
West Castleton Co.,	N. 10° E.,	40° E.,	50° E.,	A. D. H. and E. H., jr.
Castleton, west part, quarry,		30° E.,	10° E.,	A. D. H. and E. H., jr.
Castleton, Eagle Slate Co.,	N. 15° W.,	20° E.,	22° E.,	C. H. H. and E. H., jr.
Castleton, Hughes' south quarry,		20° N.E.,	10° E.,	A. D. H. and E. H., jr.
Fairhaven, Myers & Utter's,	N. 30° E.,	20° E.,	10° E.,	A. D. H. and E. H., jr.
Fairhaven, east of do.,	N. 15° E.,	34° E.,	10° E.,	A. D. H. and E. H., jr.
Fairhaven, east of do.,	N. 20° E.,	52° E.,	48° E.,	A. D. H. and E. H., jr.
Fairhaven, Wilbur's quarry,	N. 15° E.,	15° E.,	10° E.,	A. D. H. and E. H., jr.
Fairhaven, Williams & Tillson,	N. and S.,	12° E.,	5° E.,	A. D. H. and E. H., jr.
Fairhaven, Allen's north quarry,	N. and S.,	12° E.,	5° E.,	A. D. H. and E. H., jr.
Fairhaven, Williams & Tillson,	N. 10° E.,	10° S.E.,	10° E.,	A. D. H. and E. H., jr.
Fairhaven, Lloyd Jones & Co.,	N. 10° E.,	21° S.E.,	17° E.,	A. D. H. and E. H., jr.
Fairhaven, Hughes',		Dip greater than preceding,		E. H., jr.
Fairhaven, west part,	N. 20° E.,		64° E.,	A. D. H. and E. H., jr.
Fairhaven, northwest corner,	N. 65° E.,		40° S.E.,	C. B. A.
Fairhaven, southwest part,	N. 5° E.,		33° E.,	C. B. A.
Fairhaven, southwest corner,	N. and S.,		40° E.,	C. B. A.
Fairhaven, west line,	N. 40° W.,		55° N.E.,	E. H., jr. and A. D. H.
Fairhaven, west line,	N. 30° E.,		42° E.,	E. H., jr. and A. D. H.
Allen & Cooper's quarry,	N. 20° E.,	20° E.,	15° E.,	A. D. H.
Hughes' quarry,	N. 30° E.,	32° E.,	36° E.,	A. D. H.
Eagle Slate Co.,	N. 10° E.,	17° E.,	20° E.,	A. D. H.
Castleton, Wm. Hughes' quarry,	N. 20° E.,	17° E.,	20° E.,	A. D. H.
D. Hooker's quarry,	N. 20° E.,	27° E.,	34° E.,	A. D. H.
Hubbardton, west part,	N. and S.,		60° E.,	C. B. A.
Hubbardton, north part,	N. and S.,		50° E.,	C. B. A.
Wells, southeast part,	N. 20° E.,		30° E.,	A. D. H. and E. H., jr.
Wells, south part,	N. 10° E.,		30° E.,	A. D. H. and E. H., jr.
Wells, southwest part,	N. 30° E.,		55°–85° E.,	A. D. H. and E. H., jr.
Wells, north line,	N. 20° E.,		50° E.,	A. D. H. and E. H., jr.
Sudbury, southwest part,	N. and S.,	(Talcose,)	25° E.,	A. D. H.
Sudbury, east of church,	East of north,		52° E.,	C. H. H.
Sudbury, east of church,	East of north,		25° E. & 35° E.,	C. H. H.

Sudbury, east part,	N. 45° E.,		50° E.,	C. H. H.
Sudbury, east part,	N. 55° E.,		55° E.,	C. H. H.
Sudbury, north part,	N.E. and S.W.,		30° S.E.,	C. B. A.
Sudbury, north part,	N.E. and S.W.,		10° S.E.,	C. B. A.
Whiting, south part,	N. 40° E.,		10° S.E.,	C. B. A.
Whiting, near village,	N.E. and S.W.,		33° N.E.,	C. B. A.
Cornwall, south part,	N. 20° E.,		30° E.,	C. B. A.
Cornwall, east part,	N. and S.,		70° E.,	C. H. H.

Mean strike, N. 21.3° E. — 10° = N. 11° E. Do. of formation, N. 7° E. Difference, 4°.

RANGE OF GEORGIA SLATE (?) IN CHITTENDEN COUNTY.

Locality.	*Strike.*	*Cleavage.*	*Dip.*	*Observer.*
Williston, south part,	N. and S.,		35° E.,	C. B. A.
Williston, center,	N. and S.,		35° E.,	C. H. H. and E. H., jr.
Painesville,	N.45°W.–N.30°E.,		10°–40° E.,	C. H. H. and E. H., jr.
Essex, near center,	About N. and S.,		25° E.,	C. H. H.
Essex, near center,	N. 5° E.,		29° E.,	C. B. A.
Essex,	N. 15° E.,	45° E.,		A. D. H.
Colchester, depot,			48° E.,	C. H. H.
Between do. and Milton Falls,			Average 45° E.,	C. H. H.

RANGE OF GEORGIA SLATE IN FRANKLIN COUNTY.

Locality.	*Strike.*	*Cleavage.*	*Dip.*	*Observer.*
Milton, Snake Hill,	N. and S.,		Average 60° E.,	A. D. H.
Milton, north part,	East of north,		60° E.,	C. H. H.
Georgia, south part,	N. 70° E.,		18° S.E.,	C. H. H.
Georgia, south part,	N. 53° E.,		40° S.E.,	C. H. H.
Georgia, northwest part,			15°–20° S.E.,	C. H. H.
Georgia, northeast part,	East of north,		45° E.,	C. H. H.
St. Albans, east part,	N. 30° E.,		45° E.,	C. H. H.
St. Albans village,	N. 30° E.,		45° E.,	E. H. and C. H. H.
Highgate Falls,	N. 30° E.,		45°–50° E.,	C. H. H.
Highgate Falls,	N. 40° E.,		10°–20° E.,	S. R. H.
East Swanton,	N. 45° E.,		36° S.E.,	C. H. H.
Highgate, near the Falls,	N. 30° E.,	90°,		C. H. H.
Highgate,			46° E. & 67° W.,	E. H. and C. H. H.
Highgate, east part,	N. 25° E.,		60° E.,	C. H. H.
Franklin, west part,	N. 45° E.,		50° S.E.,	C. B. A.
Franklin, west part,	N. 22° E.,		60° E.,	S. R. H.
East Highgate,	N. 25° E.,		50° E.,	S. R. H.
East Highgate, Upper Falls,	N. 20° E.,		60° E.,	S. R. H.
Do., one mile west,	N. 55° E.,		60° E.,	S. R. H.

Mean strike, N. 25° E. — 10° = N. 15° E. Strike of the formation, N. 14° E. Difference, 1°.

The uniformity of the easterly dip in all three of the terrains of the Georgia slate will excite attention. There is but a single exception in the whole list, and that is evidently of a local character. The easterly dip of the slates is more uniformly to the east, than that of any one of the formations between it and the Laurentian rocks in New York.

Range, Extent and Thickness.

The presence of three distinct deposits of the Georgia slate has been already stated. The most southern deposit of the Georgia slate, which first enters Vermont from New

York in the town of Sandgate, is the largest, and is the most useful of all in an economical aspect; for a great part of it is checkered with numerous quarries of roofing slate.

Passing north from Sandgate into Rupert and Pawlet, the band of clay slate gradually widens, and attains its maximum width in Poultney and Fairhaven. Thence northerly it gradually narrows till it terminates in Cornwall, near the east village.

In Pawlet, Wells and Poultney, there is very little of special interest attached to this rock. It crops out very frequently, showing itself in beautifully rounded bosses of bright colored slates. It is not generally of such a texture that it can be used for economical purposes; and near its eastern limits it assumes somewhat of a talcoid character. As the clay slate and talcoid schists meet they are interstratified with each other. The passage from one formation to the other is not abrupt.

One who wishes to see the best development of the Georgia slate in Vermont, should examine the numerous slate quarries in Castleton and Fairhaven. So many excavations have been made, and so much material thrown out, that all the lithological characters of the rock, and the different textures and colors of the useful slates are profusely exhibited. Many of the quarries illustrate beautifully the difference between the planes of cleavage and of true bedding. The details of the position and characters of the Georgia slate in these two towns are fully stated in the description of Section VI.

There seem to have been several local elevations of the slates of this terrain. We know not how extensive these may be; whether sufficiently so as to modify our views of the thickness of the strata we know not. We noticed at the Eagle Slate Company's quarry in Castleton an elevation of a few feet, so that the same strata are repeated upon a small hill east of the quarry.

Prof. Adams, in his *Third Report upon the Geology of Vermont*, says that the line of ponds which extends from the south part of Sudbury through Wells was found to occupy the place of a long fracture and uplift of the slate formation, the mural face of which fronting to the west is found on the eastern margin of the ponds and with scarcely an interruption for the whole distance. It is worthy of notice that notwithstanding the magnitude of this fracture and uplift, no other formation is thrown up to view.

There is a peculiar concretionary slaty rock belonging to this group of rocks along the west shore of Lake Bombazine. Between Section VI. and the northern termination of the deposit in Cornwall, the same general characters are presented as upon the district already described. Section VII. crosses the deposit in Sudbury, where the slate is quite narrow, forming a mountain ridge. The most northern ledge seen is in the north part of Cornwall. It is there interstratified with the Eolian limestone; *not* resting upon the limestone as some have supposed, judging chiefly from theoretical veiws. It may, however, rest in an inverted synclinal axis, and thus the sudden thinning out of the slate be more plausibly explained.

But one of the most singular associations of this rock would seem to throw doubt upon the usual theory of the separation of the slate from the limestone. One would imagine that the slates were a formation entirely distinct from the limestones, and that the limestones form a group by themselves. We think it is extremely difficult to draw the line between the Georgia slate and the Eolian limestone which runs down the west side of the northern extremity of the Georgia slate. As one travels from Fairhaven through

Hubbardton, Benson, Orwell and Sudbury, along the limits of the two rocks, he will be perplexed by the numerous alternations of clay slate and limestone. The limestones are very insignificant in Fairhaven, but they gradually increase in amount northward until in Orwell and Sudbury the slate is insignificant in amount. The phenomena might be explained by the theory that the two kinds of rock are interstratified normally, but that in the north part of the terrain the slates have gradually dwindled till they have nearly disappeared, and that the reverse is the case in proceeding southerly, namely, the slates predominate at the expense of the limestone. We do not venture to adopt this theory, but simply state it as a view which occurred to us in the field as one that would solve many difficulties. Section VII. enumerates carefully all the different beds of slate and limestone in its path. It gives the proportions of the two rocks more carefully than Section VI. in Castleton and Fairhaven. There ought to be two other careful sections measured across these rocks to the north part of Hubbardton, and the north part of Castleton. Perhaps several points of agreement would be found in all four of the sections when they are compared together.

The second deposit which we have doubtfully referred to the Georgia slate, is colored upon the map as clay slate simply. It is a narrow strip upon the west side of the talcose conglomerates, separating them from the Eolian limestone between Westford and Starksboro'. We are almost disposed to associate with it, and thus add to its length, certain talcoid rocks associated with the quartz rock further south. Perhaps they were originally the same rock, but are now changed by metamorphism. If so, then its first appearance—beginning at the southern termination—is found upon Section VII, in the northeast corner of Brandon, in Forestdale. The rock here is probably argillo-talcose schist (Nos. $\frac{7}{100}$, $\frac{7}{101}$ and $\frac{7}{103}$ in the Cabinet.) An allied rock, holding the same geological position, occurs upon Section VIII at Ripton (Nos. $\frac{8}{62}$, $\frac{8}{64}$ and $\frac{8}{65}$ in the Cabinet.)

In the extreme east part of Bristol, at the Furnace, a similar rock, but decidedly talcoid in its appearance, is found, lying east of pure vitrified quartz rock, and west of a conglomerate. The next locality where it was noticed is in the north part of Starksboro, east of Mr. Hill's house (formerly occupied by James Chase), east of the quartz rock. Its extent is not known. We saw a similar rock next in the valley of Lewis Creek, in the southeast part of Hinesburgh, where it is properly four miles wide, although only the west edge of it is colored as clay slate upon the map. The rock, however, seems to be nearly a talcose schist. Section X. crosses it two miles further north. Passing into St. George the band of rock curves westwardly, and the clay slate now forms a conspicuous part of the deposit. The slate curves back again to the east, north of St. George, in Williston. The slate has two colors here,—the western part is black, and the eastern part is green. Southeast of the village of Williston, over a distance of two miles, the green character of the slate is very evident. The belt is wider at this point than it is at any other locality either north or south of Williston.

Between Williston Center and Winooski River the vast deposits of alluvium have concealed the rocks from view. But at Hubbell's Falls, near Essex Junction, the clay slate is conspicuously displayed in the bed of Winooski River. It is calcareous, and its junction with the Eolian is distinctly seen, though the junction itself is perplexing. The ledges of black clay slate between the Falls and Essex Center are exceedingly numerous and well characterized. At Colchester depot, and also for a mile northwesterly, the same rock occurs, dipping east. It is slightly micaceous. Near the north line of Colchester the same rock is found. It is separated from the northern deposit of Georgia slate by the Eolian limestone, which is nearly as dark in color as the slate itself. The relations of this band of slate with the Georgia slate in Milton require further investigation.

The first prominent feature in the Franklin County range of Georgia slate is Cobble Hill, in Milton. It is entirely composed of clay slate, according to Professor Thompson. The peak rises very abruptly from a plain, very similarly to Snake Hill, in the north part of the town, which is capped by a different kind of rock.

North of J. Barnes' house, in Colchester (near the tertiary deposit), and upon the north town line of Colchester, on the Checkerberry Village road, there are ledges of clay slate. There is some limestone, also, at the west foot of Cobble Hill.

West of Checkerberry Village, upon the south bank of the La Moille River, at the first bridge, there is a slate of a loose texture, cleaving naturally into "long two-edged or knife-shaped fragments." In the north part of Milton, west of Snake Hill, the rock approaches more nearly to roofing slate, and is largely developed, occupying a wide area upon Section XI. It is developed still more finely in Georgia, and northwards. The trilobites, *Barrandia Thompsoni*, etc., are found at the extreme western border of the slate, at Mr. H. Parker's house, when the rock is a micaceous sandstone. The width of the slate in Georgia is less than two miles. There is a fine exposure of clay slate near the intersection of the Vermont and Canada Railroad with the south town line of St. Albans.

In the principal street of St. Albans there is a ledge of argillo-micaceous slate, belonging to the Georgia slate group. Most of it has been removed for the benefit of travelers. This slate passes northward, and an arm extends southward east of Aldis Hill, nearly to the south line of St. Albans. The length of this arm is less than three miles.

The conglomerate composed of pebbles of limestone, which was described as one of the varieties of the Georgia slate, forms a marked feature in the aspect of the rock. The slate increases in width north of St. Albans. Its trend is now a little east of north, extending to the provincial line. Rice Hill, in Swanton, is composed of clay slate. The last appearance of the Georgia slate in Vermont is in the east part of Highgate, and the west part of Franklin. Details respecting its minute features will be found upon Section XIII, and there are particulars relating to the rock, not specified here, upon Sections XI. and XII.

Upon applying the usual rules for obtaining the thickness of strata by calculation, to the slates in the north part of Georgia, the result shows that the total thickness of the Georgia slate is at least 3000 feet. If it is folded once, the actual thickness would be one half as great, viz., 1500 feet.

The southern deposit is much thicker, though it may be reasonably doubted whether we are yet sufficiently acquainted with the true position of the strata, or of the number of the folds, to justify us in announcing conclusions. It is very certain, however, whatever view may be taken of the age of the Georgia slate, that its thickness is much greater than that of any well determined deposit of the Hudson River group ever yet described. Emmons calculated the thickness of the same terrain in New York, and found it to be as great as 25,000 feet. This was upon the supposition that none of the strata were repeated, either by elevation or plication. Though this conclusion may seem monstrous, we believe it to follow legitimately from the premises. Until it is proved that the strata are repeated in some way, we cannot see why this conclusion is not correct.

Mineral Contents.

The minerals of the Georgia slate are not numerous.

Quartz crystals are occasionally found in these rocks.

Very distinct crystals of iron pyrites occur in the roofing slates of Rutland County, and are sometimes so numerous in the quarries as to be troublesome. Some excellent specimens of them were obtained from the Eagle Slate quarry in Castleton.

Octahedral crystals of magnetic oxyd of iron also occur in the roofing slate occasionally.

In Castleton, jasper is found in small quantity. In Orwell specimens of calcite were found.

FOSSILS OF THE GEORGIA SLATE.

The following species of organic remains have been found in the Georgia slate in Vermont: *Barrandia Thompsoni* (Hall), *B. Vermontana* (Hall), *Bathynotus holopyga* (Hall), *Graptolithus Milesi* (Hall), the trail of an annelid, and unknown species of fucoids. These were all found in the most northern deposit.—Prof. Emmons has obtained several species of fossils from the Georgia slate in New York, to which he has given the following names: Three sea weeds, *Buthotrephis rigida*, *B. flexuosa* (Hall), *B. asteroides* (Fitch); two doubtful species, *Palæschorda marina*, *P. tennis* (Fitch); six graptolites, *Diplograpsus secalinus* (Hall), *Monograpsus rectus*, *Clossograpsus ciliatus*, *Staurograpsus dichotomus*, *Nemagrapsus elagans*, and *N. capillaris;* two trilobites, *Elliptocephalus asaphoides* and *Atops punctatus*. Emmons in his *Manual of Geology*, 1860, has figured a *Paradoxides trachycephalus*, which we suppose to be identical with the *Elliptocephalus asaphoides*, and with the *Barrandia Thompsoni* (Hall). He has also figured an imperfect specimen of *Paradoxides quadrispinoms*, which we suppose to be identical with the *Bathynotus holopyga* of Hall.

Prof. Hall has kindly consented to describe the three species of trilobites and a new graptolite. The descriptions of the trilobites were originally given in the *Thirteenth Annual Report of the Regents of the University of the State of New York*, 1860. The description of the graptolite is now published and figured for the first time.

NOTE UPON THE TRILOBITES OF THE SHALES OF THE HUDSON RIVER GROUP IN THE TOWN OF GEORGIA, VERMONT.

BY PROF. JAMES HALL.

In the Regents' Twelfth Annual Report on the New York State Cabinet of Natural History, I described three species of trilobites from the shales of the upper part of the Hudson River Group in Georgia, Vermont. I then referred two of these, with some hesitation, to the genus *Olenus* (Dalman), and one to *Peltura* (Milne-Edwards); following the reference to *Peltura* (*Olenus*) *scarabæoides*, as the type. A further examination of these specimens, and some others, has satisfied me of the impropriety of this reference. Although in many respects approaching to *Olenus*, these forms differ in some important features; and, in order to avoid confusion, they require a distinct designation. In their general aspect, and in some of the details, these fossils bear a resemblance to Paradoxides; from which they are at once distinguished by the less proportional elongation of the body, the smaller number of articulations of the thorax, the direction of the groove or furrow in the lateral segments, and by the form of the glabella. In the first point they also differ from *Olenus*, which, though having fewer articulations of the thorax, has a larger number than in our fossils. In their general aspect and expression, these fossils are of what might be termed a "primordial type," but yet differ from any of the trilobites in our extreme lower formations, sufficiently to be readily distinguished from them.

The genus *Paradoxides* was established by Brongniart in 1822 (*Crust. foss.* p. 30); and the fossil described by Linne under the name of *Entomolithus paradoxus*, as figured and described by Wahlenberg (Act. Soc. Upsal. 1821, pa. 31, pl. 1, f. 16), was made the type of the genus under the name *Paradoxides tessini*. Under the same genus were included *P. spinulosus*, *P. scarabœoides* and *P. laciniatus;* species described by Wahlenberg, reproducing the figures of that author, and giving an additional illustration of *P. spinulosus*.

In 1826, Dalman, admitting the genus *Paradoxides* of Brongniart, nevertheless proposed the name *Olenus* to include the four first named species; placing *P. tessini* and *P. spinulosus* in the first section, and the others in the second section of the new genus, proposing the generic name of *Lichas* for the *P. laciniatus* of Brongniart. Subsequently the three species *P. spinulosus*, *P. gibbosus* and *P. scarabœoides* have been regarded as distinct from *Paradoxides*, and made the foundation of the genus *Olenus ;* while the latter of these has more recently been placed under the genus *Peltura*.

In *Paradoxides*, as now established, we have species with broad lunate cephalic shields, with the glabella wider in front: the body or thorax has from sixteen to twenty articulations; the pygidium is narrow, with two to three and even five and eight segments, while the lateral lobes are little developed.

In *Olenus*, the cephalic shield is comparatively broader and shorter, the glabella narrowing (or not broader) anteriorly: the number of thoracic segments is from fourteen to sixteen; the caudal shield is broader than long and semicircular, the lateral lobes being more developed than in *Paradoxides*, and both marked by transverse rings or ridges.

M. Barrande makes the following comparisons between *Paradoxides* and *Olenus:*

"In establishing the family for which we have given *Paradoxides* as the type, we have indicated the characters common to the genera which constitute it. Nothwithstanding their affinities, it is easy to recognize at a glance that the *Paradoxides* are distinguished by the larger number of segments, the form of ribs, the hypostoma, the great prolongation of the cephalic limb, the very elongated eyes, and the general appearance. The only type where it is difficult to establish a strong line of demarkation, is *Olenus;* particularly when we consider *P. spinulosus*, which approaches nearest to *Paradoxides*, and which Burmeister has classed with them. Not having at our disposal the materials necessary to show fully the distinction between these two genera, we will confine our remarks to: 1, That in *Olenus*, the glabella has a form constantly narrowing towards the front, and which contrasts with those of the *Paradoxides;* 2, the lateral furrows of *Olenus* are very much inclined, and rarely unite in pairs on the axis, while in *Paradoxides* they are almost horizontal, and the two last pairs generally form two parallel branches traversing the glabella; 3, the number of thoracic segments in the first genus appears not to exceed fifteen or sixteen, which is the least number observed in the second; 4, the pygidium of *Olenus* usually differs from that of *Paradoxides* by a greater relative development of the lateral lobes. We hope that the Swedish savants will be able to define the limits between the two genera. The discovery of the hypostoma of *Olenus* would contribute much to attain this end."*

In comparing our own species with *Olenus*, we find some differences in the form of the cephalic shield but more particularly in the form of the glabella; which, however, from imperfection in the specimens, does not admit of minute comparisons. Our specimens have no more than thirteen or fourteen segments of the thorax (and the one referred to *Peltura* has eleven), instead of fifteen or sixteen, and the direction of the lateral furrow is different. The greater development and extension of the third segment of the thorax is a remarkably distinctive character, and the same feature is shown in the posterior segments of one species. The form and development of the pygidium also differs from that of *Olenus*, in the lesser lateral expansion, and absence of segments on the lateral lobes.

When we compare with *Paradoxides*, we find the cephalic shield proportionally broader and shorter, while there is no expansion of the glabella towards the front; nor do the transverse furrows extend entirely across this part, except at its base. This feature and the facial suture, though indistinct, correspond more nearly with *Olenus*.

* Barrande, *Systeme Silurien ducentre de la Bohime*, Vol. I, p. 367.

The smaller number of thoracic segments is a distinguishing feature, and the direction of the segment furrow differs essentially. In one feature, that of the greater development of the *third* segment, it corresponds with *Paradoxides*, where the *second* segment has a greater development than the others. In the extreme development of the posterior segments, in one species, there is likewise a similarity with *Paradoxides*. In the slight development of the pygidium, our fossil corresponds in some degree with *Paradoxides*.

In the perfect condition, one species appears to have been furnished with a row of nodes or spines along the dorsal ridge.

We have, therefore, although the material is imperfect, the means of showing well-marked distinctions between these forms and the allied genera *Olenus* and *Paradoxides*.

The species referred to *Peltura* has the cheeks separated, and therefore there is some obscurity about the suture margins. The expansion of the lateral lobes of the thorax is imperfect in the specimen figured; but, from examination of this and other specimens, the third segment does not appear to have been prolonged as in the two others. The pygidium has four or five rings on the axis, and the lateral lobes are expanded and the extremity rounded; moreover I am able to count but eleven articulations in the thorax: these, with other characters enumerated, seem to exclude it from generic association with the two species referred to *Olenus*. For these, excluding the one referred to *Peltura*, I would propose the generic designation Barrandia.

GENUS BARRANDIA, (n. g.)

"General form broadly ovate or elongate ovate, distinctly trilobate. Cephalic shield broad, somewhat semicircular; the width more or less than twice the length, with the posterior angles projecting in long spiniform points; the posterior margin is nearly straight or slightly concave, with a slight sinuosity at the outer angle just within the cephalic limb; the anterior and lateral margins have a thickened or elevated border, within which is a well marked groove or depression of the crust. The glabella is well pronounced, of nearly equal width throughout, or slightly narrowing and rounded in front; marked by three pairs of furrows (perhaps from two to four), the posterior one of which is nearly or quite continuous across from the posterior angles of the eyes. The facial suture has not been fully determined, but appears to extend in a curving line from the front margin to the interior angle of the eye, and from the posterior angle of the eye it turns abruptly outwards towards the postus-lateral angle of the cephalic shield.

Eyes large and well developed, elongate semilunate, extending from near the base of the shield more than half way to the anterior margin. Hypostoma broadly ovate, little longer than wide.

Thorax composed of thirteen or fourteen articulations; the axis being moderately convex, and usually much narrower than the lateral lobes (and sometimes apparently marked by a row of nodes or short spines along the summit.) Lateral lobes nearly flat; the ribs, to about the eighth or ninth, extending almost rectangularly, or slightly inclined from the axis for one-third to one-half their length, where they are bent abruptly backwards. The third segment is stronger, and much more prolonged than the others. The last segments of the lateral lobes are produced directly backwards, or sometimes a little convergent below.—The segments of the lateral lobes are marked by a broad longitudinal furrow, nearly parallel to the anterior margin; leaving an abruptly elevated ridge or border upon that side as far as the geniculation of the segment, where the groove runs along the center, dying out on the recurved extremities.

Pygidium distinct, narrow, elongated, the axis narrow, and acutely pointed; without rings? Lateral lobes narrow or obsolete, and free from transverse ridges or furrows.

The accompanying figure (Plate XIII, Fig. 1), illustrating this genus, combines characters observed in several imperfect specimens of the same species. The form of the cephalic shield is shown in two or three individuals; the glabella is crushed in all the specimens examined; but the form is made out as nearly as possible, from the materials in our possession, and cannot vary much from the truth. There are three pairs of glabella furrows anterior to the occipital furrow. In the area between the extremities of the glabella lobes and the eyes, there are on each side, in the species figured, two low oblong tubercles; but I cannot be sure that these are of generic importance, and it might be supposed possible that this appearance is due to the crushing of a prominent part of the crust, were it not that the feature is symmetrical and correspondent on the two sides.

The facial suture can be traced a little forward of the eye, but its direction on the anterior margin has not been ascertained; on the posterior margin, its direction is shown as accurately as it can be from crushed and distorted specimens. The body, or thorax and pygidium, is drawn essentially from a single individual. The line just within the free extremities of the pleura is shown in this and other specimens, and indicates the limits of the crust on the lower side. The caudal shield shows no more than the axis which is prolonged into a slender pointed spine, strengthened by a sharp elevated ridge beginning near the anterior margin, and extending to the extremity.

The entire absence, so far as can be seen, of lateral lobes of the pygidium, is a marked feature; and this especially is in strong distinction with *Olenus*.

BARRANDIA VERMONTANA.*

The accompanying figure of *B. vermontana* (Plate III, Fig. 5) illustrates also the character of the cephalic shield, and the greater strength and extension of the third articulation of the thorax. The fragment of thorax and pygidium, heretofore referred to this species (Twelfth Annual Report of the Regents), prove, on further examination, to be parts of the following or a similar species there referred to Peltura.

General form elongate; the posterior extremity obtuse. Head semioval, twice as wide as long, the posterior angles produced in short acute spines. Eyes narrow elongate; the space from the center of the head to the outer margin of the eye much greater than the cheek, and the distance from the anterior angle of the eye to the frontal margin less than the length of the eye. Glabella lobed; hypostoma broad oval.

Thorax imperfect, preserving six articulations and part of the seventh; the middle lobe wider than the lateral ones. The third articulation is much broader towards and at its lateral margin, and is prolonged obliquely downwards in a sharp spine, which reaches below the seventh articulation; the lateral extremities of the other articulations produced in short acute spines.

Another fragment, which is apparently of the same species, preserves eleven articulations of the thorax and the pygidium. The upper articulations are imperfect at their extremities; the last one is bent abruptly downwards, and terminates in a long spine on each side reaching below the pygidium. Pygidium semioval; the axis marked by four annulations, the two upper of which are faintly indicated in the lateral lobes.

This species differs from the preceding in its proportionally narrower form, the relative proportions of the parts of the head, and the short acute posterior spines. The comparative width of the middle and lateral lobes of the thorax is a very distinguishing feature.

[NOTE BY C. H. H. Plate XIII, Fig. 4, shows an outline of a more perfect specimen than any to which Prof. Hall had access. Plate XIII, Fig. 2, is a copy of the drawing made by Prof. Hall. Fig. V, on the same plate shows all the segments of the animal below the third articulation, although part of them are separated from the rest.]

In my examinations of these Trilobites, continues Prof. Hall, I had hoped to unite the three forms heretofore described, under a single genus; but on more careful comparisons, I find that the one before referred to *Peltura* is so dissimilar, that I am unable, by any proper extension of the generic characters of *Barrandia*, to include it in the same genus. In the specimens which appear to possess the thorax and pygidium entire, there are but eleven thoracic segments; the third segment is not enlarged and produced as in *Barrandia*, but, on the other hand, the anterior segments, to the number of five or six, are little prolonged at their extremities; the prolongation increases in the posterior segments, while the last one of the thorax is enlarged as it recedes from the axis, and at its broadest part makes an abrupt geniculation, turning almost rectangularly backwards, is prolonged into sharp spines in a direction parallel to the axis and extending beyond the pygidium. The axis of the pygidium is marked by three rings, while the lateral lobes are apparently smooth (in one specimen), and the entire form is semielliptical, the axis obtuse at its posterior extremity, and bordered by a smooth extension of the crust from the lateral lobes; which is in strong contrast with the preceding genus. Nor can it be properly placed under *Peltura*, which has twelve segments of the thorax,

* This and the preceding species were published as *Olenus thompsoni* and *O. vermontana*, in the Twelfth Annual Report of the Regents of the University on the State Cabinet of Natural History, pp. 56 and 60.

the cephalic shield not extended in the posterior limb, nor the last segment of the thorax produced as in the present form; while the pygidium is emarginate at the extremity, and dentate on the margin.

While the glabella has the form of *Olenus*, and the general form of the cephalic shield corresponds to that genus, the extension of the last segment of the body in spines parallel to the axis is a character of the typical species of *Paradoxides* (see *P. bohemiensis*): the pygidium is also much more nearly of the type of *Paradoxides*, than of *Olenus* or *Peltura*.

I propose therefore to designate this form by the generic name *Bathynotus*.

GENUS BATHYNOTUS (n. g.)

[Gr. βαθυς, *amplus*, and νωτος, *dorsum*; in allusion to the ample central lobe or axis of the typical species.]

General form elongate ovate, distinctly trilobate. Cephalic shield somewhat semielliptical, with the posterior angles prolonged in spiniform processes; posterior margin nearly straight across the center, and a little concave at the sides; anterior and lateral margins somewhat thickened. The facial suture (to judge from the separated parts) is very simple, extending in a slightly curving line from the front of the shield backwards, and coming to the posterior margin within the limb. The glabella is prominent and well defined, ovate in form and gradually narrowing towards the front; the occipital furrow extends directly across the glabella; the first pair of furrows above this are oblique and only slightly connected across the middle of the glabella, while anterior to these are two slight indentations. Hypostoma subcircular, with the posterior end a little wider. Eyes unknown.

Thorax composed of eleven articulations; the axis broad and prominent, wider than the lateral lobes.—Lateral lobes nearly flat, narrow; the first five or six ribs short and narrow, inclining gently backwards; the posterior ones becoming more abruptly bent and prolonged at the extremities, while the last pair are wider and stronger, bent almost rectangularly, and produced in spiniform extensions much beyond the others.

Pygidium distinct, semi-oval, the axis marked by several annulations, the lower part plain. Lateral lobes plain or marked by ridges, and extending beyond the axis in a continuous flattened expansion.

BATHYNOTUS HOLOPYGA.*

This species is represented upon Plate XIII, Fig. 3. There are but three distinct rings in the axis of the pygidium, though there is a fourth indistinct depression, which may or may not indicate a fourth ring.

The single species described in the last Report is illustrated in the accompanying figure. The specimen is a mould or impression from which most of the crust has been removed, and we have the relief from a cast made in this mould. The cheeks are separated and turned on one side; but in the drawing they are placed in symmetrical relation with the other parts of the animal. The rings of the axis are marked by a row of small spines. The great length of the spines or processes, from the posterior angles of the cephalic shield, is a remarkable feature: in this individual, their extremities must have reached as far as the eighth or ninth segment of the thorax; and in another individual, these separated parts have similar proportions.

In one imperfect specimen of this species, with narrower axis, we have eleven body rings, including the elongated posterior one; but behind this there are three annulations of the axis, the two anterior of which have somewhat the appearance of free segments, and are likewise marked upon the lateral lobes; while the pygidium below has apparently a single annulation, extending into the lateral lobe.

This one appears to be specifically distinct from the preceding, in its narrower axis; nevertheless this feature may be due to distortion, as also some other points of apparent difference.

It is to be regretted that the materials at my disposal are so imperfect as to leave some points yet in doubt; but I conceive that there can be no hesitation in admitting the generic distinction of these fossils, from those of any established genus of trilobites; and however much, therefore, we may desire to avoid the multiplication of genera, it seems to be unavoidable in the present instance.

NOTE. I may remark, in this place, that the disposition of these three species does not include two

* *Olenus* (*Peltura*) *holopyga*; Twelfth Annual Report of the Regents of the University, on the State Cabinet of Natural History, p. 61.

which I have designated as *Olenus*, in the first volume of the Palæontology of New York, pp. 256–258, Plate 67, Figs. 2, 3. One, the *O. asaphoides*, showing six of the lateral ribs of the thorax, has no ribs larger or longer than the others, though the form of the cephalic shield and the glabella are very similar to *Barrandia*, in that there are four pairs of glabella furrows, the two posterior ones of which are slightly indented across the center of the glabella. The eyes are elongated, and more curved than in *Barrandia Thompsoni*. We have, therefore, yet another undetermined material in these slates.*

GRAPTOLITHUS MILESI. (BY PROF. HALL.)

"*Graptolithus Milesi* (n. s.) Frond multibrachiate, composed of extremely slender, branching stipes, which are disposed in a bilateral arrangement upon the two extremities of a short, slender funicle (R. R. R. Figs. 2, 3 and 4, Plate XII.), without central disc, radicle short, showing as a minute process on the center of the funicle. Stipes dividing at the extremities of the funicle,and diverging at an angle of from 90° to 110°, and varying in different individuals or upon the two sides of the same, and again dividing at unequal distances above the base; giving to the best preserved specimens examined, thirty branches to one side of the frond. The bifurcations are irregular, and the number of divisions on the two sides of the frond unequal; stipe and branches slender, almost filiform, moderately flexuose, the angle of divergence of the branches becoming less and less at each successive bifurcation, and the branches becoming more parallel as they recede from the axis.

The cellules commence immediately beyond the funicle, and are very minute but clearly distinct—about thirty to thirty-two in the space of an inch; the outer margin of the cellule makes an angle of about 40° with the direction of the axis; and the line of the aperture is about 90° or a little more, appearing as rectangular to the axis. Common body capillary.

This species resembles the *G. flexilis* of the Quebec group of Canada (Report upon the Canada Geol. Survey, 1857, p. 119), but is more slender, the branches less flexuous, the cellules smaller and more closely arranged, while the outer edge makes a greater angle with the axis. It differs also in being celluliferous immediately beyond the first division of the stipe — a feature not observed in *G. flexilis*.

This species differs from all the analogous forms of the Canadian collection, where this type of graptolite was first observed, in its more slender or filiform branches. The collection referred to (See Decade II, Canadian Organic Remains) exhibits the gradual development of graptolite forms, from double stipes through the quadribrachiate and octobrachiate forms to those with numerous stipes without bifurcations above the base, and those which in their most extreme development have numerously branching stipes, as in *G. flexilis* and *G. rigidus*, to which type the species under consideration belong.

Since the discovery of this type of graptolite in the Quebec or Point Levy rocks in Canada, in 1854, similar forms have been obtained in the shales near Albany, N. Y., and I have been informed by Prof. Swess, of Vienna, that he has identified graptolites from Australia as of similar forms as those he found described in the Canada Geological Report. Plate XIII, Figs. 2 and 3, represent the two specimens of *G. Milesi*, from which the description is taken. Fig. 4 represents the central portion enlarged."

Locality. The specimen from which the figures of this species were derived, is part of a bowlder of Georgia slate, picked up in Monkton by Henry Miles, of Monkton. It was discovered almost twenty years ago, but has not been carefully examined before by any Palæontologist. The counterpart of this specimen was given to Prof. Adams, but it was probably destroyed by the burning of the State House at Montpelier, in 1857. The bowlder was probably derived from the Georgia slate, either in Georgia or St. Albans.

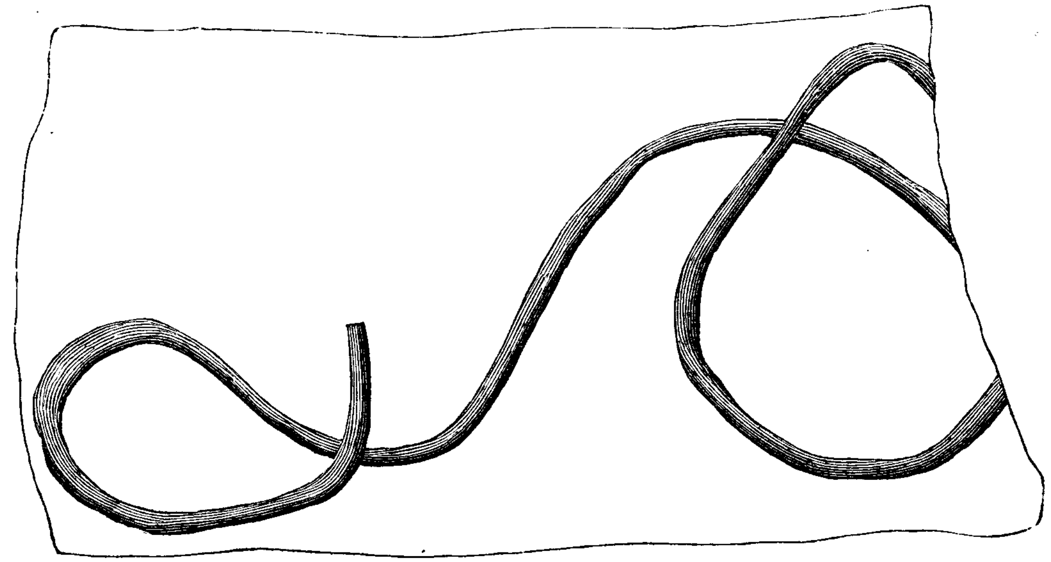
Fig. 256 represents the trail of an annelid from Georgia. It resembles some of the fossils described by Prof. Emmons.

Some fucoids have been collected from the Georgia slate, at the trilobite locality, and we have noticed multitudes of others upon slabs of sandstone in St. Albans. They have a generic resemblance to the *Palæophycus*.

*We have found, at St. Albans, another genus of trilobite, which is too indistinct to be named. The fact of its occurrence in the eastern part of the group is interesting, because it shows that we may expect to find trilobites in any part of the series. C. H. H.

Some of the larger graptolites have been found at Granville, N. Y., within a mile or two of Vermont.—Without doubt they will be found within the State. E. Hitchcock, jr. states that there are specimens in the slate of Williams and Tillson's quarry, in Fairhaven, very closely resembling fucoids and graptolites.

FIG 256.



Trail of an Annelid, Georgia.

Geological Position and Equivalency.

Before presenting the different theories of the geological position and equivalency of the Georgia slate, it will be necessary to state briefly the names and order of the groups in Europe with which all our older rocks in America must be compared. The two oldest groups of fossiliferous rocks in Europe are the Cambrian and the Lower or Cambro Silurian. To the Cambrian group are referred the following rocks: the Longmyud rocks, in Wales, 26,000 feet thick, containing annelid tracks and a supposed trilobite, *Palæopyge Ramsayi;* rocks in Ireland, about Wicklow, containing tracks of articulata and small zoophytes; Skiddaw slate, in Cumberland, containing fossil plants; in Bohemia, probably Stage A (crystalline schist), and Stage B (slate and conglomerate) of M. Barrande. No fossils known. In Scandinavia, Regio I, Fucoidarum of M. Angelin. If this group is represented in this country, it is by the Huronian rocks of Canada, and some Azoic rocks along the Apalachian ranges in the Middle and Southern States.

The Lower Silurian rocks in Wales are the Lingula flags, the Llandeilo flags, the Caradoc sandstone and Bala beds, and the Lower Llandovery beds, which are 20,000 feet thick. In Cumberland the Coniston group of Professor Sedgwick is the equivalent of the Caradoc sandstone of Wales. In Bohemia Stage C, "argillaceous schist," and Stage D, quartzite, etc., of Barrande, are the representatives of the Lower Silurian. In Scandinavia the Regiones A. olenorum, B. conocorypharum, BC. ceratopygarum, C. asaphorum, and D. trinucleorum belong to this group. In this country the equivalency of the rocks, described as Lower Silurian by Professor Hall, with these groups in Europe, is satisfactory. These groups are all represented in Vermont, viz: from the Potsdam sandstone to the Hudson River group, inclusive.

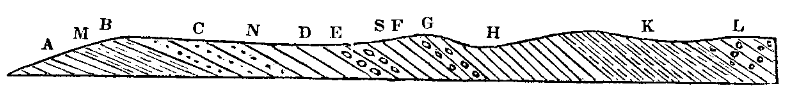
All these members contain fossils, which correspond very well with one another. We will specify a few of one group, as they may be appropriately noticed here. The "argillaceous schists," C, of Bohemia, or the "Zone Primordiale" of Barrande, are especially characterized by trilobites of the genera *Paradoxides*, *Conocephalus*, *Arionellus*, etc. The same fossils are found in the Lingula flags of Wales, and the best authorities agree in considering the Bohemia group C, and the Lingula flags as equivalent, and as forming the lowest member of the Lower Silurian. The best authorities also agree in regarding the Potsdam sandstone equivalent to the Bohemia group C, and the Lingula flags, on account of its fossils, *Conocephalites*, *Dikellocephalus*, and *Menocephalus*.

There are three views respecting the age of the Georgia slate. 1. Professor Emmons says it is the uppermost member of the Taconic system, and that the Taconic system is stratigraphically below the Potsdam sandstone,—that is to say, that the Taconic system is Cambrian. Upon pages 90, 91, of Part V. of *American Geology*, the Taconic system is directly compared with the Skiddaw slates of Cumberland. In opposition to this view, we would say that the Georgia slate rests conformably upon the Red Sandrock series, as is shown in Fig. 257, and its fossils rank it as Lower Silurian rather than Cambrian.

2. M. Barrande and Sir W. E. Logan, judging from palæontological evidence, regard the Georgia slate as equivalent to the Primordial Zone C, of Bohemia, or very nearly the Potsdam sandstone of North America. (See other letters, which follow.)

3. The stratigraphical view of the Georgia slate, which has been so ably defended by Professor Hall, seems to demand for it a place either above or equivalent to the Oneida conglomerate. This view we now proceed to illustrate by a section through the Hudson River group, Red Sandrock series, Georgia slate, etc., in St. Albans.

Fig. 257.



Section through St. Albans.

Explanation of Fig. 257.

A Hudson River shales, St. Albans Point, dip 5° E.
B Dove-colored limestone of the upper part of the Hudson River Group, dips about 25° E.
C Red sandrock series, average dip 5°–10° E.
D Georgia slate, dip 15°–20° E.
E Conglomerate of limestone pebbles, dip 42° E.
S Village of St. Albans.
F Georgia slate (argillo-micaceous), dip 45° E.
G Brecciated quartz rock, and quartz rock, on Aldis Hill.
H Georgia slate (clay slate), dip 45° E.
K Quartz rock, dip 30° E.
L Talcose schist, and talcose conglomerates.
M Village of St. Alban's Bay.
N Stratigraphical position of *Barrandia Thompsoni.*

Fig. 257 represents a section of the rocks from St. Albans Point to the east part of the town, as far as the talcose conglomerates. At the west end of the section the rock is without doubt the shales of the Hudson River group of the Lower Silurian. The dove-colored limestones above we have described as a part of the same group. The Red Sandrock series certainly rests directly upon the Hudson River Group, and the angle of their inclination is very small. D, E, F, and H, in the figure, are all parts of the Georgia slate, and perhaps G is also, though we have described it elsewhere differently, on account of its lithological character. The dip of the brecciated quartz rock on Aldis Hill is probably

the same as that of the slates adjacent. A mile north of Aldis Hill the same rock dips 15° E. The quartz rock K, overlies the Georgia slate, and is connected with the coarse conglomerates further east.

Thus we have the whole relations of the Georgia slate represented in this figure. The natural inference from these relations is that the red sandrock is of the age of the Oneida conglomerate or Medina sandstone, and the Georgia slate is still newer, and therefore Middle Silurian. All the members of the Lower Silurian, the Potsdam sandstone, the various limestones, the Utica and Hudson River slates, lie between the red sandrock and the Laurentian nucleus in New York, and the whole apparently form a successive series of newer and newer rocks, like the corresponding series in New York, from the Potsdam sandstone to the carboniferous conglomerate south of the same nucleus. If one wished to establish a palæontological system from the stratigraphical relations of the rocks containing the fossils under consideration, there is hardly a place to which we could refer with such confidence for the true order of strata as to these rocks in St. Albans. Yet it becomes us to speak with caution, because true science forbids too great certainty. Nor have we examined every ledge with compass, clinometer, and hammer, as ought to have been done in a thorough survey. The possibility of any foldings had never occurred to us until after the close of our examinations in the field.

Objections to this view arise from the possibility of foldings, perhaps connected with faults, and from palæontological evidence. Two difficulties occur in the way of supposing folds to exist: 1. The dip of the strata is much smaller than is usual in foldings of such a character as this fold must have been. 2. If C and K were composed of precisely the same material, also E and G, we could imagine either a beautiful anticlinal or synclinal axis, according to pleasure. C is dolomitic of a red or gray color; K is pure quartz, brown or of a bluish cast; E is a genuine pudding stone of limestone pebbles; G is a gritty quartz rock, sometimes brecciated, sometimes a trifle calcareous, and of a different color. The fact that these different members will not coincide when we endeavor to pair them off into folds, very seriously militates against the theory of plications.

But there may be faults. The great difficulty arising in this view is, that one fault will not satisfy the opponent of this view. The theorist's desire for faults in speculating upon these rocks is no more readily satiated than the miser's desire for gold—the more he obtains the more he wants. One instinctively shrinks back from a theory involving numerous faults. Still we will say that if any one will prove satisfactorily from stratigraphical or palæontological evidence that a series of faults are indispensable, we will not hesitate to accept his conclusions.

The principal fault which is supposed to exist by the second theory of the age of the Georgia slate must be in the vicinity of B, in Fig. 257. We have seen no evidence of it among the strata, but we would not say that its existence is impossible.

If any one is disposed to think, from the greater dip of the slates at St. Albans village (45° E.) than the mottled limestones, etc., west of them (5°–10° E.), that the slates underlie the limestones unconformably—the junction being obscured—we hope he will go to Henry Robinson's house in the north part of Georgia, three miles south of the section in Fig. 257, where he will find the union of the two rocks, as they are represented. The limestones underlie the slates, and both are inclined from 15°–20°. The superposition at the trilobite locality is not so plain, but is sufficiently clear. Just above the layers containing the fossils, there is a small bed of the red limerock interstratified with the slates, and the great mass of the dolomitic rock is only a stone's throw distant.

We would refer to the detailed description of the west end of Section VI. for the order of rocks upon a section about eight miles north of the one in St. Albans. They are similar to each other; the chief difference is the absence of the calcareous conglomerate from the Georgia slate upon Section XI. This may be an accidental oversight, because it has been seen only three miles north of the latter section. The alternations of the quartz rock and conglomerate east of Georgia depot, are different from those in St. Albans. This section passes through the trilobite locality.

A word ought to be said about the relations of the Georgia slates to the Eolian limestone. It will be necessary to suppose several singular disturbances of the strata in order to account for their present relations. In some places the slates are above the limestones, and in other localities the limestones are above the slates. The north end of the southern deposit of Georgia slate seems to be interstratified with the Eolian limestone, by a gradual passage of one into the other. Upon the supposition that there is an inverted fold, which is doubtless the correct view, we cannot yet say from structural grounds alone whether the limestone shall be considered as above or below the slates.

The range of clay slate in Chittenden County lies east of Eolian limestone, and both have the same general easterly dip. There is, however, a singular feature respecting the junction of these two formations. At Hubbell's Falls, at Essex R. R. Junction, the union of the slates and limestone is unobscured. Both rocks have a small dip away from the line of junction, though the dip of the former is greatest, while at the junction itself there are appearances of disturbance. The dip of the limestone is changed from 10° E. to nearly 90° in a few yards; and the strata of slate are nearly perpendicular also at the junction, but in a few feet change to its normal inclination of about 40° E. These facts indicate that there has been a slipping of one of these rocks above or below the other. Considered without reference to theories, the limestone seems to be the rock which was disturbed by the elevation of the slate.

We have examined every mile of the line of contact of these two rocks between Milton Falls and Starksboro, but find no case of actual junction except at Hubbell's Falls. The nearest approaches to junction elsewhere are at Colchester depot and the north part of Hinesburgh. Everywhere along the line the dip of the slates is uniformly greater than that of the limestone. Upon an examination of the junction of the Franklin County deposit of Georgia slate and the Eolian limestone, it appears that both dip east at about the same angle. The mode of their union has not yet received careful examination. Both rocks dip east, and at Milton Falls they are both nearly perpendicular.

The most plausible objection to the third view of the age of the Georgia slate arises from the character of its fossils. According to eminent authority the trilobites belonging to it correspond with those of Barrande's Primordial Zone of life, and therefore it is claimed that the rock is of the age of the Potsdam sandstone. Upon this subject we shall quote the opinions of eminent geologists, without attempting to decide between them. The whole subject evidently needs further investigation.

ON THE PRIMORDIAL FAUNA AND THE TACONIC SYSTEM OF EMMONS, IN A LETTER TO PROF. BRONN, OF HEIDELBERG.*

"*Paris, July*, 16, 1860.

"* * * * * I have recently received—thanks to the kindness of Mr. E. Billings, the learned palæontologist of the Geological Survey of Canada—a very interesting pamphlet entitled 'Twelfth Annual Report of the Regents of the University of the State of New York, 1859.' If you possess this publication, you will find there, at page 59, a memoir of Prof. J. Hall, entitled 'Trilobites of the Shales of the Hudson River Group.' This savant there describes three species under the names *Olenus Thompsoni*, *Olenus Vermontana*, and *Peltura* (*Olenus*) *holopyga*. The well-defined characters of these trilobites are described with the clearness and precision to be expected from so skillful and experienced a palæontologist as James Hall.

"Although the specimens are incomplete, their primordial nature cannot admit of the least doubt, when the descriptions are read, accompanied with wood engravings which the large dimensions of these three species render sufficiently exact. The first is 105 millim. long by 80 broad, the other two are somewhat smaller.

"The heads of the two *Oleni* being deteriorated, the furrows of the glabella cannot be recognized. The thorax has a common and remarkable character, which consists in the greater development of the third segment, the point of which is stronger and longer than in all the other pleura. This is a striking resemblance to the *Paradoxides*, the second segment of which has the same peculiarity. Besides, there is an intimate relation between these two primordial types, and we should not be surprised if America furnished us with forms uniting most of their characteristics. The pygidium of *O. Thompsoni*, the only one that is known, shows no segmentation, and attests by its exiguity its relation to a primordial trilobite. *P. holopyga*, by its whole appearance, resembles the species of Sweden so well known by the name of *P. Scarabæoides*.

"Thus all the characters of these three trilobites, as they are recognized and described by J. Hall, are those of the trilobites of the primordial fauna of Europe. This is so true, that I think I may say without fear, if M. Angelin, or any other palæontologist practiced in distinguishing the trilobites of Scandinavia, had met with these three American forms in Sweden or Norway, he would not have hesitated to class them among the species of the Primordial fauna, and to place the schists inclosing them in one of the formations containing this fauna. Such is my profound conviction, and I think any one who has made a serious study of the trilobitic forms and of their vertical distribution in the oldest formations will be of the same opinion.

"Besides, all who have seriously studied palæontology know well that each geological epoch, or each fauna, has its proper and characteristic forms, which once extinct re-appear no more. This is one of the great and beautiful results of your immense researches, which have generalized this law, recognized by each one of us within the limits of the strata he describes.

"The great American palæontologist arrived long since at the same conclusion, for in 1847 he wrote the following passage in the *Introduction* to the first volume of the Monumental Work consecrated to the Palæontology of New York.

"'Every step in this research tends to convince us that the succession of strata, when clearly shown, furnishes conclusive proofs of the existence of a regular sequence among the earlier organisms. We are more and more able, as we advance, to observe that the Author of nature, though always working upon the same plan and producing an infinite variety of forms almost incomprehensible to us, has never repeated the same forms in successive creations. The various organisms called into existence have performed their parts in the economy of creation, have lived their period and perished. This we find to be as true among the simple and less conspicuous forms of the palæozoic series, as in the more remarkable fauna of later periods.' —*J. Hall, Pal. of New York*, Vol. I, p. 23.

"When an eminent man expresses such ideas so eloquently, it is because they rise from his deepest convictions. It must then be conceived that J. Hall, restrained by the artificial combinations of stratigraphy previously adopted by him, has done violence to his palæontological doctrines, when, seeing before him the

* Proceed. Boston S. N. Hist., vol. vii, Dec., 1860, p. 371.

most characteristic forms of the *Primordial fauna*, and giving them names the most significant of this first creation, he thinks it his duty to teach us that these three trilobites belong to a horizon *superior* to that on which the second fauna is extinguished.

"In effect, according to the text of J. Hall, the three trilobites in question were found near the town of Georgia, Vermont, in schists which are superior to the *true Hudson River group*. In his work J. Hall does not go beyond indicating the horizon of certain fossils, and no one would think of asking a guaranty for such indications. But on this occasion the great American palæontologist thinks it necessary to support his stratigraphical determination by another authority, chosen from the most respectable names in geology. The following is the note which terminates his Memoir.

"'NOTE.—In addition to the evidence heretofore possessed regarding the position of the shales containing the trilobites, I have the testimony of Sir W. E. Logan, that the shales of this locality are in the upper part of the Hudson River group, or forming a part of a series of strata which he is inclined to rank as a distinct group, above the Hudson River proper. It would be quite superfluous for me to add one word in support of the opinion of the most able stratigraphical geologist of the American continent.'

"Now, when a savant like J. Hall thinks himself obliged to invoke testimony to guarantee the exactness of the position of a few fossils, it is clear that the determination of this position is difficult.

"In order to understand these difficulties I have consulted the maps and documents relating to the State of Vermont, and the country in which the town of Georgia is situated, and, although the library of our Geological Society does not contain all that one could wish on the subject, I recognized easily that Georgia is placed in the region where the order of succession of the deposits is the most obscured by foldings and dislocations; so that the position of the schists in question could not have been determined by the incontestable evidence of direct superposition. Besides, the physical appearance of these schists is not that of the rocks constituting the typical group of Hudson River. This is verified by the note of J. Hall, for it tells us that Sir W. E. Logan is inclined to make a distinct group of these schists *superior* to that of the Hudson, and which consequently *would crown the whole Lower Silurian division* of the continent.

"For the above reasons, the geological horizon on which the three *Oleni* of Georgia were found appears to me, at first view, to have been but doubtfully determined, and in complete opposition to palæontological documents.

"I do not think, then, that I weaken in the least degree the respect and confidence justly inspired by the labors of the American savants whose names have just been mentioned, when I ask them in the name of science to make new researches and new studies, that may lead to a final and certain solution of this important question.

"Doubtless—thanks to the progress of our knowledge—we are now no longer bound by the ancient conception of the simultaneous extinction and the total renovation of the faunæ. As for myself, in particular, it would not be possible to accuse me of similar views at the moment when I am publishing the explanation of my doctrine of colonies. But you will perceive that the facts which I invoke in support of this doctrine are far from sustaining the reappearance of a fauna after the extinction of the following fauna, which the three trilobites of Georgia would do, if they had really lived after the deposit of the Hudson River group.

"This reappearance would be still more astonishing, as among the three great Silurian faunæ the second fauna occupies the greatest vertical space and is probably the one which enjoyed the longest existence. Thus, to verify such a reappearance, the most incontestable proofs are required, for such a decision would compel the entire re-formation of one of our most important scientific creeds.

"Yours very truly,

J. BARRANDE."

In another letter, dated Paris, 14th August, 1860, M. Barrande says:

"You will easily perceive the interest and importance of the question, even if it were only raised on account of the three *Oleni* of Georgia; but it takes in now a much wider field, owing to a letter I have just received from Mr. Billings, official Palæontologist of the Geological Survey of Canada, who informs me that he has found lately, in the schists and limestones near Quebec, considered as being the prolongation of those in question in Vermont, nearly one hundred species, almost all new. Twenty-six of these come from a white limestone, and seem to be the true representatives of the Primordial fauna; and he cites among them *Conocephalites*, *Arionellus*, *Dikellocephalus*, etc., that is, very characteristic forms of this fauna.

"In another limestone, which is gray, he finds thirty-nine species, all different from the first, and representing, on the contrary, the most distinct types of the second fauna. Finally, the black schists furnish him with *Graptolite*, *Lingula*, etc., etc., fossils which at first sight cannot determine a horizon, because they are found upon several Silurian horizons.

"While waiting for those very obscure stratigraphical relations to be disentangled, and without committing in any manner Mr. Billings, who should preserve the independence of his opinion, I may yet express to you my view wholly personal, and of which at this moment I take the entire responsibility. I think, then, that this region of schists and limestones of Vermont, in other words the *Taconic system*, will reproduce in America what took place in England as to the Malvern Hills, and in Spain for the Cantabrian chain,—that is to say, the Primordial fauna, after having been disregarded, will regain its rights and its place, usurped for a time by the second fauna.

"You see it is a great and noble question, whose final solution will complete the imposing harmonies existing already between the series of palæozoic faunæ of America and that of the contemporaneous faunæ of Europe, leaving to each the imprint peculiar to its continent.

"I can well imagine, from the position previously taken by our learned American brethren on the subject of the Taconic system, that the final solution of which I speak will not be obtained without debate, and perhaps some wounding of self-love, for some opinions that appear to be dominant must be abandoned.

"But experience has taught me that in such cases the most elevated minds turn always first to the light, and put themselves at the head of the movement of reform. Thus, when in 1850 I recognized the Primordial fauna in the Malvern Hills, where the second fauna only had been found, Sir Henry de la Beche and Sir Roderick Murchison were the first to adopt my views, to which little by little the other official geologists agreed; Edward Forbes ranged himself publicly on my side in 1853 in 'The Geological Survey,' while others still hesitated, until now there is no longer any opponent.

"I think there will be the same experience in America, and that in a few years from this time the opinions of your savans will have undergone a great change as regards this question.

"It is a fine opportunity for Dr. Emmons to reproduce his former observations and ideas with more success than in 1844.

"Yours very truly,

J. BARRANDE."

REMARKS ON THE FAUNA OF THE QUEBEC GROUP OF ROCKS AND THE PRIMORDIAL ZONE OF CANADA. (IN A LETTER ADDRESSED TO M. JOACHIM BARRANDE, OF PARIS, BY SIR WM. E. LOGAN, DIRECTOR OF THE GEOLOGICAL SURVEY OF CANADA.)

Montreal, 31*st Dec.*, 1860.

MY DEAR M. BARRANDE:

I am much indebted to you for your letter of the 6th of August, which was accompanied by a copy of your communication to Prof. Bronn, of Heidelberg, dated 16th July. Agreeably to your request, I took an early opportunity of letting Mr. Hall have a copy of your communication to Prof. Bronn, and he received it on the 11th or 12th September, 1860.

I am of course aware, from the correspondence you have had with my friend Mr. Billings and myself, how far you are acquainted with our discoveries at Quebec. On two occasions, just previous to the receipt of your last letter to Mr. Billings (received the 8th November), I devoted the short time I could spare from other engagements connected with the Geological Survey, to further researches at Point Levi. I have satisfied myself, notwithstanding the conglomerate aspect of the bands of rock which contain our new fossils, that the fossils are of the age of the strata. Without entering at present on minute details of structure, I may say that the chief part of the specimens, found up to this time, are from two parallel out-crops, which might be taken as representing two distinct layers. If they are such, they are comprehended in a thickness of about 150 feet; but the circumstances of the case, connected with the physical structure, make it probable that the one band is a repetition of the other through the influence of an anticlinal fold or a dislocation. Both out-crops dip to the southeastward.

From the more northern out-crop which we shall call (A^2) we have obtained *Orthis* 1, *Leptæna* 1, *Camerella* 1, *Lingula* 2, *Discina* 1, *Agnostus* 3, *Conocephalites* 1, *Arionellus* 4, *Dikellocephalus* 6, *Bathyurus* 4. From the more southern out-crop (which we shall call A^3) we have *Dictyonema* 1, *Orthis* 2, *Leptæna* 1, *Strophomena* 1, *Camerella* 1, *Cyrtodonta* (?) 1, *Murchisonia* 3, *Pleurotomaria* 7, *Helicotoma* 2, *Straparollus* 2, *Capulus* 2, *Agnostus* 1, *Bathyurus* 4, *Cheirurus* 2, *Amphion* 2. From a third out-crop, which is still further southward, and supposed to be another repetition of the same band (which we shall call A^4), we have *Orthis* 1, *Camerella* 1, *Asaphus* (*A. Illænoides*) 1, *Bathyurus* 1. Tracing A^2 or A^3 round the extremity of a synclinal, and finding occasional indications of the fossils of A^2 and A^3, we arrive at a position on the south side of the synclinal. We shall call the position P. Here the band A^2 or A^3 ends, but a bed of sandstone a little above it is traceable over an anticlinal to a junction with a conglomerate band lower than A^2 or A^3, showing that A^2 or A^3 must merge into it. Call this A^1. In this we have *Asaphus* (*A. Illænoides*) 1, *Menocephalus* (*M. globosus*) 1. These two species occur in the same fragment of rock. Of all these fossils, 1 *Orthis* is common to A^2, A^3 and A^4; 1 *Leptæna*, 1 *Camerella*, 1 *Lingula*, 1 *Agnostus*, and 1 *Bathyurus*, are common to A^2 and A^3; 1 *Asaphus* is common to A^3 and A^1.

The dip at P is to the southeastward, and therefore an inverted dip. Northwest of this, and therefore above it, at such a distance as would give a thickness of between 200 or 300 feet, we have a band of shales with nodules of limestone, the nodules made up of other rounded masses in a matrix holding fossils, many of them silicified. From a few of these compound nodules we have obtained *Orthis* 11, *Leptæna* 1; this band we shall call B^1. A band like this occurs about half a mile or more to the southwestward. It may be a higher band, or it may be the same band, but we shall call it B^2. From this we obtain *Crinoidæa* (columns) 3, *Orthis* 1, *Camerella* 1, *Nautilus* 1, *Orthoceras* 1, *Leperditia* 1, *Trilobites* (2 genera undetermined) 2. In another position to the southeast, on the southeast of the same anticlinal previously mentioned, we meet with a conglomerate band supposed to be the same as B^2; but, in case it should be different, we shall call it B^3. Here we have *Orthis* 3, *Pleurotomaria* 2, *Murchisonia* 1, *Ophileta* 1, *Helicotoma* 1, *Nautilus* 1, *Maclurea* 1, *Orthoceras* 3 or 4, *Cyrtoceras* 1, *Bathyurus* 1, *Illænus* 2, *Asaphus* 1. Of all these fossils, 1 *Orthis* and 1 *Camerella* are common to B^1 and B^2, the same *Orthis* and *Camerella* with 1 *Leptæna* are common to B^1, A^4, A^3 and A^2.

To the north of all these exposures, and on the northwest side of a synclinal running parallel with the synclinal already mentioned, fossils have been obtained in a cliff of about 100 feet, composed of limestone conglomerate, thin-bedded limestones and shales. Their equivalence is not yet quite certain, but the strata are supposed to be not far removed from A^1 and A^2. We shall call this cliff A. The fossils from it are *Tetradium* 1, *Orthis* 1, *Lingula* 2, *Trilobites* (genus undescribed) 1, with a great collection of compound *Graptolidæ*, described and being described by Mr. Hall under the genera *Graptolithus* 25, *Retiolites* 1, *Reteograptus* 2, *Phyllograptus* 5, *Dendrograptus* 3, *Thamnograptus* 3, *Dictyonema* 3.

I have given you these details of localities, because as the subject requires further investigation we do not yet wish to commit ourselves entirely as to the equivalency of separate exposures. But there is no doubt that the whole is one group of strata deposited under one set of alternating circumstances. The whole fauna, as known up to the present time, is composed of

Articulata,	36 species.
Mollusca,	55 "
Graptolidæ,	42 "
Radiata,	4 "
	137

Of this fauna not one species is found in the Anticosti group, where we have a gradual passage from the fauna of the Hudson River formation to that of the Clinton, and not one of any formation higher than the Chazy. Mr. Billings recognizes one species *Maclurea Atlantica* (Billings), as belonging to the Chazy, and six species as belonging to the calciferous. They are *Lingula Mantelli* (Billings), *Camerella* undescribed, *Ecculiomphalus* undescribed, *Helicotoma uniangulata* (Hall), *H. perstriata* (Billings), and one remarkable species of an undetermined genus, like a very convex *Cyrtodonta*, which occurs both at Mingan and Point Levi. All of the forms, particularly the trilobites, remind the observer of those figured by Dr. D. Dale Owen from the oldest fossiliferous rocks of the Mississippi Valley, while independent of the six species identical with Chazy and calciferous forms, there are many others closely allied to those found in the latter formation in Canada.

From the physical structure alone no person would suspect the break that must exist in the neighborhood of Quebec, and, without the evidence of the fossils, every one would be authorized to deny it. If there had been only one or two species of an ancient type, your own doctrine of colonies might have explained the matter, but this I presume would scarcely be applicable to so many identities in a fauna of such an aspect. Since there must be a break, it will not be very difficult to point out its course and its character. The whole Quebec group, from the base of the magnesian conglomerates and their accompanying magnesian shales to the summit of the Sillery sandstones, must have a thickness of perhaps some 5000 or 7000 feet. It appears to be a great development of strata about the horizon of the Chazy and calciferous, and it is brought to the surface by an overturn anticlinal fold with a crack and a great dislocation running along the summit, by which the Quebec group is brought to overlap the Hudson River formation. Sometimes it may overlie the overturned Utica formation, and in Vermont points of the overturned Trenton appear occasionally to emerge from beneath the overlap.

A series of such dislocations traverses eastern North America from Alabama to Canada. They have been described by Messrs. Rogers, and by Mr. Safford. The one in question comes upon the boundary of the Province, not over a couple of miles from Lake Champlain. From this it proceeds in a gently curving line to Quebec, keeping just north of the fortress; thence it coasts the north side of the Island of Orleans, leaving a narrow margin on the island of the Hudson River or Utica formation. From near the east end of the island it keeps under the waters of the St. Lawrence to within eighty miles of the extremity of Gaspé. Here again it leaves a strip of the Hudson River or Utica formation on the coast.

To the southeast of this line the Quebec group is arranged in long narrow parallel synclinal forms with many overturn dips. These synclinal forms are separated from one another on the main anticlinals by dark gray and even black shales and limestones. These have heretofore been taken by me for shales and limestones of the Hudson River formation, which they strongly resemble, but as they separate the synclinals of the Quebec group must now be considered older. I am not prepared to say that the Potsdam deposit in its typical form of a sandstone is anywhere largely developed above these shales, where the shales are in greatest force. Neither am I prepared to assert its absence, as there are in some places masses of granular quartzite, not far removed from the magnesian rocks of the Quebec group, which require further investigation; but, from finding wind-mark and ripple-mark on closely succeeding layers of the Potsdam sandstone where it rests immediately upon the Laurentian series, we know that this arenaceous portion of the formation must have been deposited immediately contiguous to the coast of the ancient Silurian sea, where part of it was even exposed at the ebb of tide. Out in deep water the deposit may have been a black partially calcareous mud, such as would give the shales and limestones which come from beneath the Quebec group.

In Canada no fossils have yet been found in these shales, but the shales resemble those in which *Oleni* have been found in Georgia (Vermont.) These shales appear to be interposed between eastward dipping rocks equivalent to the magnesian strata of the Quebec group, and they may be brought up by an overlapping anticlinal or dislocation. We are thus led to believe that these shales and limestones, which may be subordinate to the Potsdam formation, will represent the true primordial zone in Canada.

Mr. Murray has this season ascertained that the lowest rock that is well characterized by its fossils in the neighborhood of Sault Ste. Marie, near Lake Superior, really belongs to the Birdseye and Black River group, and that it rests upon the sandstones of Ste. Marie and Lacloche, the fossiliferous beds at the latter place being tinged with the red color of the sandstone immediately below them. These underlying Lake Superior rocks may thus be Chazy, calciferous, and Potsdam, and may be equivalent to the Quebec group and the black colored shales beneath. The Lake Superior group is the upper copper-bearing series of that region, and rests unconformably upon the lower copper-bearing series, which is the Huronian system. The upper copper-bearing series holds nearly all the metals, including gold, and so does the Quebec group, each making an important metalliferous region. Each when unmetamorphosed holds a vast collection of red colored strata. The want of fossils in the Lake Superior group makes it difficult to draw lines of division, but if any part represents the primordial zone, I should hazard the conjecture that it is the dark colored slates of Kamanistiquia, which underlie all the red rocks.

Professor Emmons has long maintained, on evidence that has been much disputed, that rocks in Vermont, which in June, 1859, I for the first time saw and recognized as equivalent to the magnesian part of the Quebec group, are older than the Birdseye formation; the fossils which have this year been obtained at Quebec pretty clearly demonstrate that in this he is right. It is at the same time satisfactory to find that the view which Mr. Billings expressed to you in his letter of the 12th July, to the effect that the Quebec trilobites appeared to him to be about the base of the second fauna, should so well accord with your opinions; and that what we were last spring disposed to regard at Georgia as a colony in the second fauna, should so soon be proved, by the discoveries at Quebec, to be a constituent part of the primordial zone.

I am, my dear M. Barrande,

Very truly yours,

W. E. LOGAN.

M. JOACHIM BARRANDE, Rue Mezière No. 6, Paris.

LETTER FROM JAMES HALL, PALÆONTOLOGIST OF NEW YORK, TO THE EDITORS OF THE AMERICAN JOURNAL OF SCIENCE AND ARTS.

Gentlemen,—In the Twelfth Annual Report of the Regents of the University* upon the State Cabinet of Natural History, I published descriptions of three species of trilobites from the shales of the town of Georgia, in Vermont, referring them to the age of the Hudson River group. These trilobites had been in my possession for some two years or more; and knowing the great interest that would attach to them, whenever published, I had waited, hoping that some new facts might be brought out touching the stratigraphical relations of these rocks in the town of Georgia.

After the descriptions had been printed and a few copies distributed, I learned that Sir William Logan was at that time actually investigating the rocks of that part of Vermont. Desiring to know the results of his latest researches in regard to the stratigraphical relations of these rocks, I withheld the final publication till the meeting of the American Association for the Advancement of Science, in Springfield, and there showed to Sir William my descriptions as they now stand in the Report, and I then received his authority for the addition of the note which was appended.

This in a few words is a simple history of the matter relating to the publication of these species. I made no remarks or comparisons with the primordial fauna of Barrande in Bohemia, knowing that these features would be at once recognized by every palæontologist; while their reference to the genus *Olenus* showed my appreciation of the nature of the fossils.

I received a copy of the communication of Mr. Barrande, from Sir William Logan in September, a few days before setting out for my field duties in Wisconsin. Since my return to Albany, constant and pressing occupation has left me no time to consider a reply to a question of so much importance.

Later discoveries in the limestones associated with the shales at Quebec, leave no longer a doubt, if any could have been entertained before, that the shales of Georgia, Vermont, are in the same relative position; and we must regard these trilobites as belonging to the same fauna with the species enumerated by Sir William Logan as occurring in the Quebec group. Left to palæontological evidence alone, there could never have been a question of the relations of these trilobites, which would at once have been referred to the primordial types of Barrande.

* The same to which Mr. Barrande refers in his text to Prof. Bronn, p. 312. The preceding communications sufficiently explain the subject under discussion.

Sir William Logan yields to the palæontological evidence, and says, "*there must be a break.*" He gives up the evidence of structural sequence which he had before investigated and considered conclusive; and having heretofore relied upon the opinion of the distinguished Geologist of Canada in regard to a region of country to which my own examinations had not extended, I have nothing left me but to go back to the position sustained by palæontological evidence. Let us for a moment examine this palæontological evidence.

The identifications of the fossils of the Quebec group, certainly show a remarkable agreement between the trilobites of this group and those of the Potsdam sandstone in the occurrence of *six species* of *Dikellocephalus* and one of *Menocephalus;* while the occurrence of many others is in agreement, or not incompatible, with the fauna of the Potsdam and calciferous sandstones. The comparative values of the trilobitic faunæ of this group and of the primordial zone of Europe, as established by Barrande, is better shown in a tabular form which I here append :

The Crustacean fauna of the primordial zone of Europe.

Paradoxides,	These genera are all limited to the *fauna primordiale*, and none of the other European genera of trilobites are known in this fauna.
Olenus,	
Peltura,	
Conocephalus,	
Ellipsocephalus,*	
Hydrocephalus,	
Sao,	
Arionellus,	
Agnostus,	Of the first and second fauna.
Amphion,	Placed with doubt in the first fauna, and is well developed in the second fauna.

The Crustacean fauna of the Quebec Group.

Conocephalus,	Genera of the *primordial zone.*
Arionellus,	
Agnostus,	A genus passing from the first to the second fauna.
Dikellocephalus,	Genera of the Potsdam period.
Menocephalus,	
Bathyurus,	Quebec group.
Asaphus,	Of the second fauna.
Illænus,	Of the second and third fauna.
Amphion,	Of the second fauna; and doubtfully of the first fauna in Sweden.
Ceraurus=Chierurus,	Of the second and third Silurian faunæ, and of the Devonian fauna.

We have therefore, in the Quebec group, two established genera of the primordial zone; one *Agnostus*, which passes from the primordial to the second fauna; one, *Amphion*, cited as doubtful in the first fauna in Sweden, and known to be in the second; and three—*Asaphus, Illænus* and *Chierurus*, which begin their existence in the second fauna. Of these, Asaphus begins and ends in the second; Illænus begins with the second and continues to the third; while Ceraurus=Chierurus begins in the second, extends through the third Silurian, and appears in the Devonian fauna.

Bathyurus is a new genus, and as yet has no stratigraphical value in comparisons. Those which I have described as Olenus have proved to be not true Oleni; and though much resembling that genus, are nevertheless distinct; and I have proposed the names *Barrandia* and *Bathynotus* for the two forms.† These have yet no stratigraphical value, except so far as their relations to establish genera may aid in that direction.

The genera *Dikellocephalus* and *Menocephalus* are of the Potsdam group; and so far the Quebec group is in parallelism with the Potsdam and calciferous strata.

* Not Elliptocephalus of Emmons.

† Thirteenth Annual Report of the Regents of the University of N. Y., on the State Cabinet of Natural History, Albany, December, 1860.

Of the other genera, we know Asaphus, Illænus and Ceraurus (=Chierurus) in the Trenton limestone and Hudson River groups; Illænus and Ceraurus in the upper Silurian strata of Niagara age, or the third fauna of Barrande; while Ceraurus occurs also in the Devonian of Europe. Amphion is known in the second fauna in Europe, and, doubtfully in the first.

Ceraurus does not occur in this country, so far as I know, above the Niagara group; though known in the Devonian rocks of Europe.

The following tabular arrangement of the genera found in the Quebec group will serve to express more distinctly the relations of the Crustacean fauna of these rocks.

The letters at the head of the columns have the same references as those used in the communication of Sir William Logan.

	A	A^1	A^2	A^3	A^4	B^1	B^2	B^3
Arionellus,		—	4					
Conocephalus,		—	1					
Agnostus,		—	3	1				
Dikellocephalus,		—	6					
Menocephalus,	—	1	—	—	—			
Bathyurus,		—	4	4	1			1
Barrandia, } *Shales of Georgia, Vt.*								
Bathynotus, } *Shales of Georgia, Vt.*								
Amphion,				2				
Asaphus,		1			1			1
Illænus,								2
Chierurus (Ceraurus),				2				
Leperditia,							1	
Lingula,	2	—	2					
Discina,		—	1					
Orthis,	1	—	1	2	1	11	. 1	3
Leptæna,		—	1	1		1		
Strophodonta,		—		1				
Camarella,			1	1	1		1	
Cyrtodonta ?				1				

	A	A^1	A^2	A^3	A^4	B^1	B^2	B^3
Maclurea,								1
Murchison,				3				1
Pleurotomaria,				7				2
Helicotoma,				2				1
Straporollus,				2				
Capulus,				2				
Ophileta,								1
Nautilus,							1	1
Orthoceras,							1	3 or 4
Cyrtoceras,								1
Crinoidal columns,							3	
Tetradium,	1							
Dictyonema,	3			1				
Graptolithus,	25							
Retiolites,	1							
Reteograptus,	2							
Phyllograptus,	5							
Dendrograptus,	3							
Thamnograptus,	3(?)							

In this table we find, of previously recognized trilobites of the primordial fauna, two genera and five species; of previously known genera of the second and third faunæ, *four genera* and eight species; *two genera* before known in the Potsdam sandstone and seven species; and of Agnostus, which is of the first and second faunæ, two species; and one new genus with nine species.

These are certainly very curious results; and a modification of our views is still required to allow four genera and eight species, (or leaving out Amphion) three genera and six species of the trilobites of the second fauna, to be associated with two genera and five species of trilobites of the primordial fauna, and yet regard the rocks as of primordial origin.

The Brachiopodous genera, Lingula, Discina, Orthis, Leptæna and Strophomena, have a great vertical range, and are known in the lower and upper Silurian, and most of them in the Devonian; while Camarella so far as known is a lower Silurian form of the second fauna (perhaps also in a lower position.)

Of the Gasteropoda, Maclurea and Ophileta are restricted to lower Silurian rocks, but occur mainly in the second fauna. The other genera occur likewise in the second fauna and in the upper Silurian rocks, as well as some of them in Devonian. The same is true of the Cephalopoda enumerated.

Tetradium is known in the second fauna of the lower Silurian rocks, and in the upper part of the Hudson River group at the west. Dictyonema is a genus known from lower Silurian to Devonian strata.

Graptolithus proper extends to the Clinton group of New York; and the same is true of Reteograptus. Thamnograptus occurs in the rocks of the Hudson River group near Albany, and in the Quebec rocks. Phyllograptus and Retiolites are known in the Quebec rocks only; while the typical form of Dendrograptus occurs in the Potsdam sandstone, and, likewise, in three other species, in the Quebec rocks.

We find, therefore, in the other genera except trilobites, very little satisfactory evidence, on which to rely in the present state of our knowledge, for determining the position of these strata.

In the present discussion, it appears to me necessary to go further, and to inquire in what manner we have obtained our present ideas of a primordial, or of any successive faunæ. I hold that in the study of the fossils themselves there were no means of such determination prior to the knowledge of the stratigraphical relations of the rocks in which the remains are inclosed. There can be no scientific or systematic palæontology without a stratigraphical basis. Wisely then, and independently of theories, or of observations and conclusions elsewhere, geologists in this country had gone on with their investigations of structural geology. The grand system of the Professors W. B. and H. D. Rogers had been wrought out not only for Pennsylvania and Virginia, but for the whole Apalachian chain; and the results were shown in numerous carefully worked sections. In 1843, '44 and '45, I had myself several times crossed from the Hudson River to the Green Mountains, and found little of importance to conflict with the views expressed by the Professors Rogers in regard to the chain further south, except in reference to the sandstone of Burlington, and one or two other points, which I then regarded as of minor importance.

Sir William Logan had been working in the investigations of the geology of Canada; and better work in physical geology has never been done in any country.

This then was the condition of American Geology, and investigators concurred, with little exception, in the sequence based on physical investigations. As I have before said, our earliest determinations of the successive faunæ depend upon the previous stratigraphical determinations. This I think is acknowledged by M. Barrande himself, when he presents to us, as a preliminary work, a section across the center of Bohemia. With all willingness to accept M. Barrande's determination, fortified and sustained as it is by the exhibition of his magnificent work upon the trilobites of this strata, we had not yet the means of parallelizing our own formations with those of Bohemia by the fauna there known. The nearest approach to the type of primordial trilobites was found in those of the Potsdam sandstone of the northwest, described by Dr. D. D. Owen; but none of these had been generically identified with Bohemian forms;* and the prevailing opinion, sanctioned as I have understood by M. Barrande, was that the primordial fauna had not been discovered in this country, until the rediscovery of the Paradoxides Harlani, at Braintree, Mass. The fragmentary fossils published in Vol. I, Palæontology of New York, and similar forms of the so-called Taconic system, were justly regarded as insufficient to warrant any conclusions. It then became a question for palæontologists to decide, whether determinations founded on a physical section, in a disturbed and difficult region of comparatively small extent, were to be regarded as paramount to determinations founded on examinations, like those of the Professors Rogers, extending over a distance in the line of strike of five or six hundred miles; and those of Sir William Logan over nearly as great an extent from Vermont to Gaspé.

It is not possible for me, at this moment, to give the time necessary for a full discussion of this important subject. In presenting these few facts in this form, I am far from doing it in the spirit of cavilling, or as an expression of distrust in any direction. It is plain that the case is not met in M. Barrande's plan of successive trilobitic faunæ; and the facts yet brought out do not serve to clear up the difficulty. It is evident that there is an important and perplexing question to be determined,—one that demands all the wisdom and sagacity of the most earnest inquirers, and one which calls for the application of all our knowledge in stratigraphical geology and in palæontology;—one in which coöperation, good will and forbearance are required from every one, to harmonize the conflicting facts as they are now presented. The occurrence of so many types of the second fauna in the rocks at Point Levi, associated with a smaller number of established primordial types, offers us the alternative of regarding these strata as of the second stage, with the reappearance of primordial types in that era, or of bringing into the primordial zone several genera heretofore regarded as beginning their existence in the second stage: in either case, so far as now appears, conflicting with the scheme of M. Barrande in reference to the successive faunæ of trilobites as established in Bohemia and the rest of Europe.

For myself I can say, that no previously expressed opinion, nor any *"artificial combinations of*

* The glabellæ of small trilobites undistinguishable from Conocephalus occur in the Potsdam sandstone near Trempaleau, Wisconsin, on the Mississippi River.

stratigraphy previously adopted" by me, shall prevent me from meeting the question fairly and frankly. I have not sought a controversy on this point, but it is quite time that we should all agree that there is something of high interest and importance to be determined in regard to the limitation of the successive faunæ of our older palæozoic rocks. I am very truly yours, &c.,

JAMES HALL.

Albany, N. Y., January 23, 1861.

[NOTE BY E. H., SENIOR.]

July 18, 1861. Still more recently, other able and voluminous papers have appeared on the subject discussed above. In the *Canadian Naturalist and Geologist* for June, is an elaborate paper, by Sir William Logan, on the Quebec group and the upper copper-bearing rocks of Lake Superior. In the latest Bulletin of the Geological Society of France, we have an article of more than 100 pages, entitled, *Documents anciens et noveaux, sur le Fauna primordiale et le Systeme Taconique eñ Amerique ;* by Barrande.

We have neither time nor space to give even a synopsis of these papers. They contain essentially the same views as are expressed above by these distinguished savans. We feel, however, somewhat in doubt whether we understand Barrande in his concluding remarks. After quoting from Sir W. Logan's paper given above, he says, "Terms so clear and positive need no commentary. It is a formal recognition, by Sir W. Logan, of the Taconic System at the base of the Lower Silurian. Prof. Emmons could not wish the assent of a more respectable authority, which cannot fail to secure the adhesion of all American geologists." (*Bulletin—Seance de* 4 *Fevrier*, 1861, p. 320.) Now we understand Sir William to suggest, that "these shales and limestones (of Quebec and Georgia), are subordinate to the Potsdam sandstone"—a deep sea deposit, going on at the same time with the arenaceous deposit nearer the shore ; whereas Prof. Emmons places his Taconic System *below* the Potsdam sandstone, in the same position as the Cambrian and Huronian System. Does he then recognize the Taconic System as understood by its author, or can it be that Barrande has mistaken his meaning ? We apprehend that the discussion of this subject is yet only begun.

TALCOSE CONGLOMERATES.

MAGNESIAN SLATES: *First Annual Report upon the Geology of Vermont*, 1845 ; *by Prof. C. B. Adams.*

Under this head we are about to describe rather an indefinitely defined group of rocks, constituting what many would call the western part of the western range of the talcose schist. It seems to be associated with the quartz rock in its south part, and may be of the same age. Partly for this reason we have used the same color to designate the extent of the two rocks, upon the Geological Map.

Lithological Characters.

The different varieties of rocks associated together in this belt are the following:

1. Sandstones.
2. Breccias.
3. Quartz rock.
4. Calcareous rocks.
5. Novaculite schist.
6. Talcose schist.
7. Coarse conglomerates.

The sandstones are few. Beds of sandstone may be seen near St. Albans, upon the narrow spur running up to Aldis Hill from the main belt in Fairfax. They are of a dull gray color, having shining, wavy surfaces, which are covered with an argillaceous film. They split into good flagging stones. Other beds upon Aldis Hill are intermediate between sandstone and hyaline quartz.

The brecciated rock of this group is also in St. Albans. It may be seen in the south part of the village, and is of a dull gray color, composed of fragments of quartz rock of the same color.

The quartz rock is more abundant. There are beds of it in the extreme west part of Huntington. Probably such beds are common between Hinesburgh and Westford. The blunt spur, extending from Fairfax to Milton Falls, is mostly quartz rock. In passing from Georgia depot to Fairfax Center, there are alternations of quartz rock and conglomerate. The number of these beds, and their relation to each other, need investigation. At a saw mill, a short distance east of Georgia depot, the quartz rock is very finely developed. From La Moille River to the east part of St. Albans, the quartz rock may be traced continuously, in quite a wide belt. In St. Albans it occurs upon the high hill east of Aldis Hill. It is of a dun color here, and is thickly traversed by segregated veins of white quartz. A section from the Georgia slate at its southern extremity, in St. Albans, to North Fairfax, passes over the following rocks in an ascending order: Georgia slate, silicious limestone, quartz rock, talcose schist, coarse talcose conglomerate and talcose schist. These are all members (except the first) of the group of rocks now described. There are other beds of quartz rock in Fairfield and Sheldon.

The calcareous rocks are not numerous. They are mostly limestones; but occasionally the talcose schist is calcareous. The latter variety are found in Richmond and Jericho. The limerocks are found in Milton, at the corners of the four towns of Georgia, St. Albans, Fairfax and Fairfield. In Fairfield, No. $\frac{11}{326}$; Sheldon Four-corners, No. $\frac{12}{118}$; and in the west part of Franklin, Nos. $\frac{13}{155}$ to $\frac{13}{158}$. The limestones in Franklin are quite abundant, and are of good quality. An analysis of one of them gives the following results:

Silica, or insoluble silicates,	30,419
Peroxyd of iron and alumina,	2,331
Carbonate of lime, . .	35,419
Carbonate of magnesia, .	31,831
	100,000

This proves to be a dolomite. Its locality is about a mile west of the village of Franklin. The rock has been burned for lime. There is not a distinct bed of dolomite, but rather a series of small beds interstratified with talcose schist. There is a similar calciferous rock near Judge Hubbard's house, a mile north of the village. Dolomite is still more abundant north of Judge Hubbard's near the Canada line. The rock here is properly the Winooski limestone.

The novaculite schist is the most common in the north part of the deposit. Upon Section XI, it is found at Fairfax, Fairfield, Westford, and Milton. See Nos. $\frac{11}{227}$, $\frac{11}{235}$, to $\frac{11}{239}$, $\frac{11}{242}$, $\frac{11}{327}$, and $\frac{11}{328}$. It occurs, also, at Sheldon Four Corners, $\frac{12}{120}$, and is very abundant in Franklin. See Nos. $\frac{13}{150}$ to $\frac{13}{154}$. It is one of the most common rocks in Franklin.

The talcose schist is the most common rock in the belt colored as talcose conglomerates, insomuch that we have sometimes questioned the propriety of separating this belt stratigraphically from the azoic talcose schist. Lithologically, the two talcose schists cannot be distinguished from each other; and the want of magnesia is probably common to both. The belt is mostly composed of talcose schist in Starksboro, Hinesburgh, Fairfield, and Sheldon. In the other towns the other varieties predominate. The towns where the talcose schist predominates have not been examined as carefully as the others; hence we conjecture that when they are carefully studied, the amount of talcose schist will be diminished. We must, however, except a section across the south part of Hinesburgh, upon a branch of Lewis Creek. The rock there is wholly composed of talcose schists and grits. Nos. $\frac{9}{138}$, $\frac{9}{142}$, $\frac{9}{143}$, $\frac{9}{147}$, $\frac{9}{150}$, $\frac{9}{154}$, $\frac{9}{156}$, $\frac{10}{108}$ to $\frac{10}{110}$, $\frac{11}{224}$ to $\frac{11}{226}$, $\frac{11}{228}$, $\frac{11}{233}$, $\frac{12}{134}$, $\frac{12}{122}$, $\frac{12}{123}$, represent this variety in the State Cabinet. Many specimens of talcose schist, when weathered and smoothed by eroding agencies, display a number of small rolled grains of quartz, etc., in its composition. This is a talcose sandstone; and probably most of the talcose schist of this belt is only an altered sandstone.

The last named variety, the coarse conglomerate, is the characteristic rock of the group. In general it may be called a coarse conglomerate cemented by talcose grit. Probably the coarse conglomerates along the east border of the quartz rock, already described, in Clarksburgh, Mass., in Sunderland, Peru, Wallingford, Chittenden, Pittsford, and Lincoln, belong to this group. We should have little hesitation in extending the color of the talcose conglomerates along the east border of the quartz rock to the Massachusetts line, only it would be very narrow.

In Chittenden there are evidences of a large amount of conglomerates between the quartz rock and gneiss; and this district has not been explored, chiefly owing to the wild nature of the country, and the difficulty of discovering ledges beneath the immense piles of detritus. But ledges of a gneissoid conglomerate are numerous near the west line of Chittenden, midway between the north and south villages. Bowlders of coarse conglomerate, similar to that in Richmond, are found in the north part of Chittenden. They have a peculiar appearance, and must therefore have been derived from ledges in the vicinity, rather than those known further north.

In Lincoln the pebbles of this conglomerate vary in size, from grains of sand to pebbles as large as hens' eggs. They are mostly blue hyaline quartz, whose original source is unknown. It resembles the conglomerate in Wallingford. The next locality to the north that we have explored, is in the west part of Richmond, extending over the town line to Jericho, Williston, and Essex. The pebbles are generally about three inches in diameter, and never exceed six. They are granite, a fine-grained variety, evidently derived from Laurentian rocks, quartz rock, dolomite, and silicious limestone. There is nothing about the pebbles by which the age of the conglomerate can be determined with certainty, though there is a strong resemblance between the limestone pebbles and certain beds of limestone *in situ* near Burlington. See Nos. $\frac{9}{130}$ to $\frac{9}{137}$, etc., in the Cabinet.

In Fairfax there are pebbles of clay slate in a similar conglomerate, which were probably derived from the Georgia slate. In the northwest part of Fairfax this conglomerate is developed more finely than at any other locality, and it is there interstratified with quartz rock. The pebbles are generally of the same size as those in Richmond, though some of the fragments of slate may be a foot long. They are granite, quartz rock, talcose schist and clay slate of every variety. The cement is sandstone, filled with so many crystals of

magnetite that the compass is affected by them, even at a distance from the ledges. A surface six feet long and a foot wide, was carefully examined, and several pebbles of granite exhibited upon it, seem to have been elongated since their fixture in the rock. Upon another ledge near by, there were seen also many long and narrow pebbles of slate, which may have been elongated; but it is difficult to be positive, since it is very natural for slaty rocks to break into long fragments. We have seen no ledges of conglomerate in the State that illustrate the lithological character of a conglomerate so distinctly and beautifully as this. Three large specimens of it in the Cabinet, Nos. $\frac{12}{137}$, $\frac{12}{138}$ and $\frac{12}{139}$, though excellent, give a very poor idea of the appearance of the ledges. This belt of conglomerate is about thirty rods wide.

There are other ledges of conglomerate between Fairfax and the Canada line; but they would not attract much attention. The rocks are mostly novaculite schists.

Divisional Planes.

We have preserved three observations respecting the position of joints in these talcose conglomerates.

Locality.	*Strike.*	*Dip.*	*Observer.*
Richmond, northwest corner,	About E. and W.,	90°,	C. H. H.
Fairfax, center,	N. 50° E.,	39° N.,	C. H. H.
Fairfax, east of center,	N. 40° W.,	25° S.W.,	C. H. H.

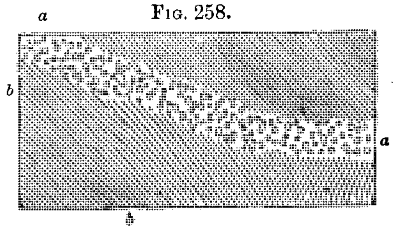
We have preserved the following observations respecting the position of the laminæ of foliation.

Locality.	*Strike.*	*Dip.*	*Dip of Strata.*	*Observer.*
Fairfax, center,	N. 38° E.,	70° E.,	33° E.,	C. H. H.
Fairfax, east of center,	N. 35° E.,	77° E.,	11° N.W.,	C. H. H.
Fairfax Falls,	N. 43° E.,	80° E.,	12° N.W.,	C. H. H.
Westford, north part,	N. 23° E.,	90°,	7° southerly,	C. H. H.
Richmond, west corner,		50° E.,	23° E.,	C. H. H.

Foliation is a term scarcely used yet by American writers. It is a change in metamorphic rocks analogous to cleavage. It is a *crystalline lamination*, or a separation of the different mineralogical compounds into distinct layers, much resembling strata. We suppose that generally in Vermont the foliation coincides with the stratification. Most observers would call the laminæ of foliation cleavage planes. In fact the chief difference between the two classes of planes, is that the former are the result of the same forces as cleavage planes, only they have continued to operate for a longer time, and are not confined to argillaceous rocks.

Fig. 258 represents the perpendicular face of a ledge in a quarry in the northwest part of Richmond.—A jointed plane existed in the ledge, cutting through it, and the workmen have removed all the rock upon the south side of the seam, so that the end of the ledge exhibits its internal structure upon a smooth face about eight feet square. The rock is entirely composed of talcose grit, except a belt of conglomerate, *a a*, dipping irregularly in the same direction, but at a different angle of inclination, from what we have usually called strata, *b b*, everywhere else. There are no lines of separation between the pebbles and the adjoining schists; they pass into one another insensibly, yet are perfectly distinct. We discovered nothing else in the vicinity similar to this case.

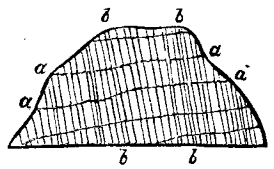
Fig. 258.



Similar examples were observed in the north part of Westford. Strata of conglomerate are subdivided by laminæ of foliation. A stratum of conglomerate, six inches thick, changes from one kind of material to another in the space of a few feet. It may be compared to a beam of timber, one half of which has been sawed into boards, while the other half is as compact as it was at the first. So this is partly conglomerate, and partly schist.

The most satisfactory cases of foliation in these conglomerates may be seen between the village of Fairfax, and Fairfax Falls, in ledges upon the banks of La Moille River, which in high water are covered by the river. The rock is a green sandstone, showing the grains of sand in its composition chiefly after the surface has been smoothed by abrasion and slight decomposition of the cementing substance. Divisional planes, *b b*, in Fig. 259, cross the ledge regularly, separated by narrow layers, and are inclined 77° E. The strike of these planes varies very little from that of certain marks *a a*, running through the ledge nearly at right angles to the former, being inclined 11° N. W. The latter markings are rather obscure, and may be seen to the best advantage, by observing them from a stand point at some distance from them. The marks *a a*, are generally about a foot apart. When carefully examined, they appear to be thin layers of schist, an eight of an inch wide, being composed of finer laminæ, which are inclined at a different angle from that of any other planes in the ledge. These marks may be compared to a section of a thin plate of fibrous gypsum. No. $\frac{11}{233}$ in the Cabinet shows some of these markings. Had this ledge been upon one of the islands of Lake Champlain, where two sorts of planes abound upon the same exposure, we should have pronounced it a clear example of planes of cleavage intersecting those of stratification, the latter being almost obliterated.

Fig. 259.



Section in Fairfax.

A question of much importance is naturally suggested by these observations. In the western part of Vermont, where metamorphism has not changed the aspect of the rocks so much as in the central and eastern parts, the marks of strata are nearly obliterated. Now why should not the marks of stratification be entirely obliterated in the more thoroughly metamorphosed regions, so that the observations recorded of various dips and strikes of the strata are those of foliation? We confess that our confidence in the truthfulness of our observed marks of stratification have been somewhat shaken by these examples of foliation.— If some additional planes could be discovered elsewhere in the metamorphic rocks, to correspond with marks of strata, it would confirm this view. And it would probably reduce the very great thickness, which we have felt compelled to ascribe to the strata of the different species of metamorphic rocks.

STRIKE AND DIP OF THE STRATA.

The following observations have been made respecting the strike and dip of the strata of these talcose conglomerates:

Locality.	*Strike.*	*Dip.*	*Observer.*
Wallingford, Calico rocks,	N. and S.,	65°–80° W.,	A. D. H.
Chittenden, west part,	N. 20° W.,	30° E.,	C. H. H.
Lincoln, west part,	East of north,	40° E.,	C. H. H.
Lincoln, west part,	East of north,	75° E.,	C. H. H.
Starksboro,	N. 10° E.,	90°,	C. B. A. and C. H. H.
Starksboro, north part,	N. 10° W.,	55° E.,	C. B. A.
Starksboro, northeast corner,	N. 10° W.,	50° E.,	C. B. A.
Hinesburgh, southeast part,	N. 10° W.,	53° E.,	C. B. A. and C. H. H.
Hinesburgh, east part,	N. 15° W.,	49° E.,	C. B. A.
Hinesburgh, east part,	N. and S.,	30° E.,	A. D. H.
Hinesburgh, east part,	N. and S.,	47° E.,	C. H. H.
Hinesburgh, east part,	N. and S.,	40° E.,	C. H. H. and A. D. H.
Richmond, northwest corner,	N. 10° E.,	55° E.,	C. H. H.
Jericho, southeast corner,	N. 10° E.,	12°–25° E., (?)	C. H. H.
Jericho, west part,	N. 15° W.,	52° E.,	C. B. A.
Jericho, east part,	N. 14° E.,	65° E.,	Z. T.
Jericho, center,		70° E.,	Z. T.
Jericho Corners, a mile northwest,	N. 25° E.,	Easterly,	A. D. H.
Jericho Corners,	N. 5° E.,	60° E.,	Z. T.

Jericho Corners,	N. 25° E.,	50° E.,	A. D. H.
Essex, southeast corner,	N. 30° E.,	53° E.,	C. H. H.
Essex, southeast part,	N. and S.,	50° E ,	C. H. H.
Essex, south part,	N. 12° E.,	54° E.,	C. B. A.
Essex, east part,	N. 10° E.,	60° E.,	Z. T.
Westford, north part,	N. 23° E.,	90°, (7° S. ?)	C. H. H.
North Westford,		74° E.,	C. H. H.
Fairfax Falls,	N. 43° E.,	80° S.E.,	C. H. H.
Fairfax, west of Falls,	N. 35° E.,	77° E.,	C. H. H.
Fairfax, east of village,	N. 38° E.,	70° E.,	C. H. H.
Fairfax, west part,	N. 22° E.,	53° E.,	C. H. H.
Fairfax, west part,	N. 20° E.,	24° E.,	C. H. H.
Fairfax, northwest part,	N. 10° E.–N. 20° E.,	Dip east,	C. H. H. and S. R. H.
Fairfax, west part,	N. 22° E.,	53° E.,	C. H. H.
Fairfax, west part,	N. and S.,	40° E.,	S. R. H.
Milton Falls,	N. and S.,	48° E.,	C. B. A.
Milton, Snake Hill,		Nearly horizontal,	C. H. H.
Milton, Snake Hill,		0°–10° E.,	A. D. H.
Georgia, southeast part,	N. 22° E.	20° E.,	C. H. H.
St. Albans, east part,	N. 45° E.,	30° S.E.,	C. H. H.
St. Albans, south part of village,		7°–10° E.,	C. H. H.
Sheldon, near middle,	N. 45° E.,	82° S.E.,	C. B. A.
Sheldon, south part,	N. 35° E.,	60° N.W.,	S. R. H.
Franklin, west of village,	N. 40° E.,	25° S.E.,	C. H. H.
Franklin, do., one mile N. of previous observation,	N. 40° E.,	25° S.E.,	C. H. H.
Franklin, two miles west of village,	N. 22° E.,	60° E.,	S. R. H.
Franklin, near Canada line,	N. 45° E.,	50° S.E.,	C. H. H.

This table of inclinations most clearly points out the fact that the almost invariable dip of the strata is to the east. There are only two exceptions, and these are of a local character. There are two spurs projecting from the terrain; one to the north at St. Albans; the other to the south, terminating at Milton Falls. If we are to regard any of these dips as inverted, these projections may furnish the materials out of which we may construct a single plication. We prefer not to conjecture the number, position or order of any inverted axes in the talcose conglomerates; hoping that after geologists agree respecting the age of the Georgia slate, some light may be thrown upon this group of rocks, which is superimposed stratigraphically upon the Georgia slate.

Range, Extent and Thickness.

The talcose conglomerates form one simple deposit, extending perhaps from Wallingford, certainly from Lincoln, to the northern line of the State. Some of the deposits of quartz rock, talcose schist, and conglomerate in Pittsford and Chittenden, undoubtedly are of the same age as this group, but we are unable at present to separate them from the quartz rock. We think that the talcose grits and mica schists, upon Sections VII. and VIII, in Brandon, Goshen, and Ripton, belong to this group. A good section crosses this group of rocks in Lincoln. See Fig. 248. The following is the order of rocks there, beginning at the bottom: Quartzite, talcose schist, talcose sandstones, talcose schists, talcose sandstones, talcose schists, talcose grits, conglomerates, talcose sandstones, talcose schists and grits. In the north part of Starksboro, the rock at the west border of this talcose belt is a dark colored grit, standing upon its edges, and running N. 10° E. In the south part of Hinesburgh no rocks were observed in crossing the formation, except talcose schists and grits. Add to those on the route of Section IX. in the middle of Hinesburgh, beds of quartz rock. Along Winooski River the rock is conglomerate, interstratified with talcose schists and grits.

The following is the order of rocks along Winooski River, beginning at the bottom of the series in Essex, and extending to the west part of Richmond: Talcose schist, conglomerate, with seams of green gritty slate, talcose schist, chlorite schist with quartz, talcose schist with sandstone, talco-argillaceous slate, talcose schist and sandstones, talcose schist, coarse conglomerates (typical locality), and talcose schists.

Professor Thompson called these rocks Taconic, and has left the following notes concerning them, as they occur in Chittenden County. "These rocks commence east of [the clay (Georgia?) slate and Eolian limestones], and extend eastward; but I shall not attempt to assign their eastern limits. They consist in this country entirely of schistose rocks, composed chiefly of quartz, and most of them are more or less magnesian. There is a belt extending through Westford and the east part of Essex and the west part of Jericho to Winooski River, which is quite chloritic. This is often thick-bedded, and answers very well for a building stone, though rather soft. It has been considerably used for doorsteps, and has been transported to Burlington for that purpose. Some of the strata appear to be a coarse sandstone, or rather a fine conglomerate. Some places, as at Essex, exhibit a fine compact magnesian slate, which is easily sawed into any form, and is used as a fire-stone. In many places the slaty laminæ are covered with a fine talc glazing. The slate generally, in the eastern part of the county, may perhaps be called talcose, but the proportion of talc in the greater part of it is quite small. The predominant mineral in it is quartz, and it often occurs, either white or limpid in seams several inches in thickness."

The following is the order of the members of this belt of rocks between Georgia depot and East Fairfax: Gritty greenish slate, quartz rock, gritty greenish slate, quartzite, conglomerate, quartz rock, talcose sandstones, talcose schists and sandstones, talcose sandstones, coarse conglomerates, and finally talcose grits and sandstones.

The following is the order of the members of this belt of rocks four miles further north, but the section does not extend further east than the sixth member of the previous section: Silicious limestone, quartz rock, talcose schist, coarse talcose conglomerate, talcose schists. This conglomerate is what is described as the very fine ledge in North Fairfax. The first three members of this group in the east part of St. Albans are slaty quartz rock, compact dun-colored quartz rock, checkered with white veins and talcose grits.

A spur runs down to Milton from Georgia depot, composed, as far as Milton Falls, of quartz rock and dolomite. The northwest side of Snake Hill, in Milton, as well as its southeast side, is made up of quartz rock and sandstone. The top of the hill is sandstone, occasionally slaty, mixed with layers possessing the variegated colors of the Winooski marble. Southwest of Milton Falls the calcareous and magnesian rocks prevail. At Georgia depot the rock is quartz, succeeded on the northeast by mica schists. Near the corner of the four towns, Fairfax, Georgia, Fairfield, and St. Albans, there is an impure limestone interstratified with quartz rock. The underlying portion of the quartz runs off to St. Albans like an arm, through Prospect Hill and Aldis Hill, terminating in the midst of a clay slate, which is almost a black sandstone. The overlying portion of the

quartz is well developed along the east part of St. Albans, Swanton, and Fairfield, but is succeeded gradually by a novaculite schist and limestone in Sheldon and Franklin. The latter is especially abundant in the west part of Franklin. Between the Union and Brick Churches, in Sheldon, there is a great development of conglomerate. In the north part of Franklin, for about three miles, it would be difficult to name the rock, as it is a dirty massive compound between limestone and novaculite schist.

We have made no estimate of the thickness of the talcose conglomerates, but know that they must be very thick. They must be 2,000 or 3,000 feet thick at the least calculation, where they are fully developed, as in the northern part of the State. We suppose that this belt of rocks includes the Sillery sandstones of Canada. These are estimated at 4,000 feet, in Canada.

No fossils have been found in the talcose conglomerates.

Mineral Contents.

The minerals of these rocks are very few. The most common, and in some places they are quite large, are veins of milky and transparent quartz, with which there may be associated large crystals of quartz. We noticed such specimens in Westford and Fairfax.

Some of the fine veins of red hematite in Fairfield belong to these rocks; though most of them may be referred to the talcose schist.

In Franklin there is some novaculite, though of inferior quality.

Another mineral is dolomite, which passes into a rock.

Geological Position and Equivalency.

The talcose conglomerates are the continuation into Vermont of the upper part of the Quebec group and the Sillery sandstones of Canada. The Canada Survey now regard them as lower Silurian; but formerly considered them of the age of the Oneida conglomerate of the middle Silurian. Prof. Emmons, we suppose, would class them among his Taconic rocks, and therefore as older than Silurian.

The view that we shall present of the age of these rocks is, at present, less definite than the others, and will eventually, probably, coincide with one of the first two theories. If we were to decide stratigraphically, we must say that it is newer than the Georgia slate, since it invariably overlies it, unless the dip be inverted. It is the eleventh belt of rocks, overlying the Laurentian rocks of Northern New York.

We regard this belt of rocks as associated with the quartz rock of the southern part of the State. It may be of identically the same age, or in other words, the strata of quartz rock pass gradually into strata of talcose conglomerate. It is for this reason that we have used the same color to represent both the quartz rock and the talcose conglomerates, upon the Geological Map.

As the thickness of the conglomerates is greater than that of the quartz rock, so the synchronism of the two may not be perfect. Some of the conglomerates may be newer, and some may be older than the quartz; but we think the same general age may be ascribed to both.

It is in this belt of rocks that the great metamorphic agency is fully developed, which has so altered the rocks of New England. Hence we have no fossils to guide our way, and it is exceedingly difficult to progress satisfactorily without them. But future discoveries will make evident what is now obscure; and the time is coming when not merely the metamorphic rocks of Vermont, but of all New England, will be mapped as critically as those formations that are now exactly defined by fossils.

EOLIAN LIMESTONE.

BY E. HITCHCOCK, SEN.

This is a new designation for one of the most important and useful rocks of Vermont It furnishes the beautiful white marble, equal to the finest Italian, known all over our country as a product of this State. Such a rock, and such marble, certainly deserve a name as beautiful and euphonical as the epithet Eolian. But its origin needs explanation.

The fine mountain in East Dorset, known generally as Dorset Mountain, and sometimes as Green Peak, contains the most remarkable display of white and gray limestone in New England — perhaps in the United States. The strata here are piled upon one another to the height of nearly 1800 feet, in a nearly horizontal position, and capped by a few hundred feet of talcoid schist. Near the top of the limestone is a large cave, descending westerly from the eastern precipitous face of the mountain.

In a Report on the Geology of Massachusetts, we gave the name Berkshire limestone to this rock, because it is well developed in Berkshire county of that State. Prof. Emmons called it Stockbridge limestone, because large quarries of it exist in that town. On the same principle Rutland ought to be the prefix instead of Stockbridge, because the Rutland quarries are much the largest. But since the largest development we know of this rock is seen in Dorset Mountain, we had resolved in this Report to call it Dorset limestone. In the Autumn of 1860, however, the Geological (Senior) Class in Amherst College, having gone to Vermont to assist in measuring a section across the Green Mountains, found themselves in the vicinity of Dorset Mountain, and could not resist the temptation to ascend it and propose a name for it.* They called it Mount Eolus, in honor

*It has long been the custom with the Geological Class in Amherst College, to seek out yearly some mountain without a name, or with a bad one, and by a few ceremonies to impose a name upon it. If the public like the name they will adopt it, although it always requires a good deal of time to bring it into general use. Hence they always try to select a good name. In order to be good, it should be derived from one of three sources: 1. Indian. 2. Classical; that is, Greek or Latin, or Hebraic. 3. Historical. The two first are the best sources. Such a name should awaken no low or vulgar associations. It should be one that would be graceful and ennobling in poetry, and yet it should be easily pronounced and appreciated by all. Such names as Norwottuck, Nonotuk, Mettawampe, Pocomtuc, Rock Rimmon, Nutonk, Hygeia, and Kilburn Peak, answer these conditions, and have been proposed by different classes for different mountains. Eolus is eminently appropriate, being classical, poetical, euphonical, and suggestive. It may not be inappropriate to insert the following account of the ceremony of naming Eolus, written by one of the party:

"Leaving Rutland about 1 o'clock Saturday morning, we made our way as speedily as possible on the Western Vermont R. R., towards the little village of East Dorset. Time and language would fail to describe the feelings and postures of our company as we proceeded. Some, desirous to sleep, were coiled up like a chicken in an egg shell; others, fearful of being carried too far, were using the few energies of life remaining, to keep themselves and others awake. Turkeys never went to roost more gladly than the Seniors sought their beds in the hotel. Some, however, had to abide in the manger, for there was no room for them in the inn. Morning came very early in East Dorset; and after a short but wholesome breakfast, we screwed up our courage for the ascent of the mountain, which rose nearly three thousand feet above us. This mountain has hitherto gone by the name of Dorset Mountain—which is no name at all, as there are more mountains than one in Dorset; and it seemed good to us to append a name, which might be called its own. And for that reason we ascended its steep marble sides. After climbing nearly half its height, we came to the marble quarries of Messrs. Holley, Field & Kent, where is obtained stone which rivals the Carrara, and goes by the name of the "Vermont Italian." It has, more clearly than any other American marble, the metallic ring so peculiar to the best Italian marbles. It is very hard, containing a large per cent. of silica, and is consequently very durable. The strata lie in a horizontal position, which is different from that of the strata in the neighboring mountains, and implies a different formation. It is quite evident that the mountain was forced up into its present position by

of the God of the Winds, which were confined by him in a cave; and there is quite as much reason for supposing the cave on this mountain to have been the place where they were imprisoned, as to locate it in the far inferior mountain of Stromboli. We too cannot resist the temptation to apply a name so euphonical and appropriate to this elegant rock, so like the Carrara marble, which probably skirts the western base of some of the Apalachian ridges from Canada to Alabama.

If the proprietors of the marble quarries on this mountain should yield to a similar temptation, *Eolian* marble may become as famous in the future history of this country as the Carrara marble has been in that of Italy. We do not know wherein the former is inferior to the latter.

lateral pressure. Leaving the quarries, we ascended to within about seven or eight hundred feet of the summit, where we found a sort of table ground and an enormous cave, in the solid marble. It was here we proposed to take a stand and shoulder the responsibility of god-father to this mountain. When all had arrived and order was restored, Mr. C. H. Hitchcock commenced the services of christening with a few brief remarks, relative to the birth, growth, and maturity of the mountain, mentioning, also, the brotherhood of mountains for which Amherst boys had become the sponsors. Then with his geological hammer he broke the bottle he held in his hand (thereby reminding us of Gideon and his troop), and the mountain was christened with the sprinkling of water, which flowed from its own marble heart,

MOUNT EOLUS.

"After this ceremony, Mr. Field, who accompanied the class up the mountain, made a brief address, stating his pleasure in the occasion, and his conviction that the name would be a permanent one.

"A striking little episode next followed, in which four personifications of the winds came blowing and whirling among the crowd, enough to make us all shiver. It is needless to state that the most gaseous personages in the class were selected for this purpose.

"A poem was then read by one of the number, giving some sketch of the life of the winds and their keeper, Eolus. We have not been able to obtain a line of this for publication.

"After the poem, an ode, written by W. M. Pomeroy, was sung, to the good old air of "Mount Pisgah." The cold mountain air rung well as the song came out.

"The ceremonies of christening over, we proceeded to enter the cave, with candles in hand and cautious feet beneath. Down, down we went into the marble bowels of the mountain, and nobody knows how far we might have gone, had time or courage permitted. We made the cavern ring with our songs, and sundry jokes made our voices ring with laughter till we were obliged to make our way out and down the mountain.

"Perhaps it would be well to state our reasons for giving the name of Eolus to the mountain. It is a fact that, in some kinds of weather air is perceived to blow from the cave, and it is very easy to understand how we found here a resemblance to the cave in which the ancient Eolus kept the winds restrained, or sent them out at his pleasure. Homer makes the winds to have had their residence in Thrace, if we haven't forgotten our Greek, and Prof. Tytler says, Thrace is any rough, hilly country; hence it is easy for us to establish our theory, for no certain knowledge ever prevailed but that this was the mountain, and this the cave, in our New England Thrace, where Eolus kept the winds, or sent them out by the stroke of his inverted spear.

"Equinox is a mountain in full view from Eolus, and is said to have been so named from its being covered with clouds about the time of the equinoxes. In order that Eolus might receive a recognition from its nearest neighbor, it was voted to give him a letter of introduction to Equinox.

"Nearly east of Eolus is Mt. Stratton, one of the Green Mountain range, on which, in 1840, was held the greatest political gathering ever held in Vermont. Webster was present, and so great was the enthusiasm that the people camped out over night.

"On arriving at the foot of the mountain we learned that our expenses in East Dorset were nothing to us, for which we heartily thanked the people and cheered them, though not half so well as their kindness cheered us. By the kindness of Mr. Field we were allowed to bring away fine specimens of the Eolian marble.

"Through the same gentleman we received a very kind invitation from Mr. Orvis, of the Equinox House, in Manchester, to spend the Sabbath with him as his guests. We returned sincere thanks for his kindness, and regretted that duty should call us in another way. The temptation to stay away another day from our ALMA MATER was great, but we resisted. Mr. Field kindly offered to have the following engraved in the marble over the mouth of the cave:

MOUNT EOLUS.
CLASS OF '61.
AMHERST COLLEGE.
October 13th, 1860, A. D.

"At length, after a farewell shout for Eolus and Dorset, we entered the cars and started for home. We returned to Amherst very weary, but satisfied that we never had a more glorious time."

We have a special object in giving these details. In New England generally, and certainly in Vermont, are many noble mountains that have no established name, and many more whose names are simply those of the towns in which they are situated, and many others whose

The position and parallelism of the Eolian limestone in Vermont are remarkable and difficult. But we reserve our remarks on these points, as well as upon its metamorphism, till we have presented the usual details representing the formation, drawn up by C. H. H.

SYNONYMS.

GRANULAR LIMESTONE: *Professor Chester Dewey's Geological Map of a part of Massachusetts, etc.; American Journal of Science and Arts,* I. Series, Vol. VIII, 1824.

BERKSHIRE LIMESTONE: *Geological Report of Massachusetts,* 1832 *and* 1834; *by Prof. Edward Hitchcock.*

STOCKBRIDGE LIMESTONE: *Prof. E. Emmons' works upon the Taconic System,* 1838–1860.

METAMORPHIC LIMESTONES OF THE LOWER SILURIAN: *Geology of the First District of New York; by W. W. Mather;* 1843.

STOCKBRIDGE LIMESTONE: *Reports on the Geology of Vermont; by Prof. C. B. Adams,* 1845–1848.

METAMORPHIC TRENTON LIMESTONES: *T. S. Hunt, quoting from Sir W. E. Logan, American Journal Science and Arts,* II. Series, Vol. IX, p. 19.

STOCKBRIDGE LIMESTONE: *Appendix to Thompson's Vermont; by Zadock Thompson;* 1853.

DORSET LIMESTONE: *Elementary Geology; by E. Hitchcock and C. H. Hitchcock;* 1860, page 411.

EOLIAN LIMESTONE: *The present Report.*

Lithological Characters.

There is more variety in the limestones of this group than in almost any other formation in the State. Yet the variations are mostly slight in themselves chemically, but considerable as far as external appearance is concerned. We shall not attempt to give all the particulars under this head, but after stating the general characters would refer to the fourth topic, and to the descriptions of the general sections for particulars.

names, derived from some trivial circumstance, are not only devoid of all good taste, but convey only low or ridiculous ideas. Of this class are such names as Bull Mountain, Cow Mountain (of which there are three in the State), Mt. John, Mt. Tom, Bone Mountain, Tug Mountain, Hog Back Mountain, Snake Mountain, Cobble Mountain, Rattlesnake Mountain, Potato Hill (two at least), Swearing Hill, Joe's Hill, Devil Hill, Mutton Hill, and Camel's Rump or Hump. Which of these names would not spoil the best poetry ever written? Nor can they be used by any community without lowering its standard of taste.

Is not here, then, an important work for the literary part of the citizens of the State, especially its Colleges? Can they not, by proposing good names for the unnamed or badly named mountains, induce the public to use them? At present, very few have names against which good taste does not reluctate. The most numerous class are those which bear the names of the towns in which they are situated. But these are mere geographical designations, and ought not to be regarded as names at all. Another class bear the names of individual men. These are better; but, after all, few of us have names that are fit to be placed upon a mountain. Certainly neither John, nor Joe, nor Tom, nor Tobey, are appropriate.

In regard to some of these names, which are objectionable on account of their low associations, it would obviate the difficulty to translate them into Greek or Latin. Thus, how much better would Mt. *Ophis* (the Greek for snake), sound than Snake Mountain. What an improvement upon Rattlesnake Mountain would it be, to call it Mt. *Crotalus* (the Latin name for this snake!) What a mighty gain, I may add, would it be, to substitute Mt. *Leo* for Camel's Rump; which Latin name for lion is suggested by the resemblance of this mountain to a crouching lion. So, Mt. *Cervus* (a deer) might take the place of Buck Mountain, and Mt. *Taurus* (the bull) that of Bull Mountain. Mt. *Albus* (white) might well replace the Black Mountain of Dummerston (there is another, we believe, in the State), which, strange to say, is composed of *white* granite, showing itself conspicuously; and by what absurd freak of fancy it was called *black,* and still retains that name, we can explain only by the rule of contraries.

We divide all the varieties chemically, into six general divisions:

1. Pure carbonate of lime, embracing the marbles and most of the limestones.
2. Impure carbonate of lime; the lime portion in excess.
3. Magnesian limestones and dolomites.
4. Clay slate, often calcareous.
5. Talcose schist and talcose limestones.
6. Quartz rock, and those calcareous rocks in which silicious matters are the principal ingredients.

I. & II. CARBONATES OF LIME.

Under this head we notice particularly the white, colored, variegated and brecciated marbles, saccharoid limestone, variously colored limestone, sparry limestone, brecciated limestone, micaceous limestone, etc. The most important analyses of them are given in the adjoining table.

Locality.	Silica and insoluble matters.	Alumina & Perox'd of Iron.	Carbonate of Lime.	Carbon'te of Magnesia.	Water and Loss.	Total.
White marble, Hyde's Quarry, Rutland,	1.68	.59	97.73			100.00
Greenish marble, do., do.	14.55		85.45			100.00
Statuary marble, Brandon,	.29		99.51	trace.	.20	100.00
Marble, Manly's Quarry, Sudbury,			100.00			100.00
Marble, Phelp's Quarry, Middlebury,			100.00			100.00
Marble, Sheldon & Slason, W. Rutland,	.57		98.00			
Limestone, North Dorset,	1.49	1.79	85.18	13.11		101.57
Limestone, Milton,	1.50	1.01	84.45	12.14	.90	100.00
Marble, Sudbury,		.30	99.70			100.00

The greater part of the group the non-magnesian — usually the pure limestones, as in Massachusetts, occupy the west border, and the dolomites the eastern; and the intermediate varieties occupy the interspace. The more silicious limestones are also near the eastern or upper limit, as the limestone is gradually passing into quartz rock. The white statuary marbles have very little impurity in them, as the analyses show. The colored marbles have various impurities in them, from whence their colors are derived. The variegated marbles, like those at Whiting Station on the R. and B. R. R., have a considerable foreign matter in them, and on this account are often more beautiful. A marble at Arlington is made of fragments of a previous bed, which have been cemented together by stalactitic matter; i. e., by carbonate of lime held in solution by the water trickling among the fragments. This is a very interesting example; showing, as it does, that a marble may be broken into fragments and be reconsolidated by the help of small amounts of water permeating the mass. The varieties of marbles are very great, and we refer to the Economical Report for a full description of them.

The limestone in the vicinity of the marbles is more or less saccharoid. Or it may be slaty, granular and more or less friable. In general the Eolian limestone of Vermont is whitish and rather firm; not very granular, and though metamorphic not generally abundantly crystalline. In this respect it is less marked than in Massachusetts, perhaps for the reason that it is not so highly metamorphic. A few specimens are like the most beautifully crystalline marble from one of the quarries at North Adams, made up of completely formed crystals of calcite. But it is difficult, after all, to describe the general character when other varieties are so common. The white limestone in Colchester differs from that further south, by its fineness of texture and disposition to break up into exceedingly angular fragments. It is harder and less liable to decomposition. We refer to the limestone burnt extensively for lime, by Messrs. Penniman and Bates. It differs from the dove-colored limestone of the Hudson River group by superior hardness. But the marble of Shelburne does not differ from that in Middlebury.

Occasionally the limestone does not appear to have been metamorphosed, but retains its original dark color. This is well marked at Hubbell's quarry, in Bennington. From fifteen to twenty feet of bluish and reddish-white marble are underlaid by seven feet thickness of black, thin and even-bedded limestone, with a conchoidal fracture; having the same general appearance as the most compact limestones of the Trenton group. It is remarkable that such a bed of rocks should occur in the midst of metamorphic rocks, especially as the underlying stratum contains the best formed crystals of calcite we have seen in the whole formation, and that in great abundance. No fossils were found in Bennington after a very cursory search for them, but were seen at two other localities of apparently unaltered limestone, in Danby and Orwell.

Upon the hill east of Danby corner, there is a considerable thickness of dark gray limestone, with a few grains of sandy particles. It resembles the limestone of the calciferous mica schist formation, and is what we should imagine that limestone to have been originally. Its extent is considerable, along the middle range of limestone. A few bowlders from Shaftsbury, full of fossil corals (?), (resembling *Stromatopora*), are obviously from this vicinity. East of Orwell village, is another locality of dark-colored limestone, containing fossils. It is softer than that from the preceding localities, and of a lighter color.

A similar fossiliferous unaltered limestone is found one mile northwest from Middlebury, and doubtless others may be specified. A dark bluish-colored limestone is often found between the marbles and overlying slates, as at Mt. Eolus, Mt. Anthony, etc. At the latter locality the rock contains masses of hyaline quartz, exceedingly fetid when fractured. At other places, as in Burlington, Brandon and Milton, the limestone is slate-colored and quite soft. This is a variety apt to contain traces of fossils. Sometimes it merges gradually into the softer argillaceous rocks.

The variety sparry limestone is used by us to denote certain beds of limestone, either white or darker colored, that are completely traversed by veins of calcite or quartz. Prof. Emmons extends the term to embrace all the limestones of the middle range of limestone in Vermont, or that running through Danby, as well as that in Fairhaven, etc., running north until it meets the other limestones. He describes* its structure as follows: "The color of this rock is uniformly gray; it weathers unevenly, by which a rough surface is formed, disclosing in its composition silex and other earthy matter. It contains numerous veins of white calcareous spar which give it a checkered appearance, and masses of quartz which traverse the rock in an irregular manner. It dips to the east at the line of junction with the slate; but after passing further east, the dip is changed to south-west, where it rises into moderate hills whose steepest slope is upon the east side.

*Geol. Second Dist. N. Y., pages 151, 152.

"To recognize the characters of this rock, is a matter not at all difficult in the field: its curiously checkered surface, formed by a milk-white calcareous spar branching out upon a gray ground, will, it is conceived, be sufficient to create in the mind an image of the rock, and to impress upon it one of its most characteristic features. This rock is sufficiently pure to be used for quicklime; and accordingly, along the belt of country which it traverses, it is often burned for that purpose. When it is sound, and can be obtained in suitable masses free from flaws, it would form a handsome veined and clouded marble.

"A subject worthy of attention, is the period of the formation of the veins of calcareous spar. From observations upon other rocks, which contain fossils, which of course are free from calcareous veins at the time of their inclosure in the materials of the rock, it seems to be established that those veins were formed subsequent to the consolidation of the rock; for it is not an uncommon circumstance to discover a shell traversed by a vein of spar.—The most rational explanation appears to be, that the rock in drying, or in the process of consolidation, cracked in every direction; and into the fissures thus formed, pure calcareous matter was infiltrated in sufficient abundance to fill the open space thus produced in drying."

The term sparry limestone should not be limited to the Eolian limestones; for we find it in other groups, as for instance in the Hudson River group, as we have already shown. It denotes simply a lithological variety of several rocks.

A brecciated limestone is found at several localities in this formation. At South Wallingford (Nos. $\frac{5}{206}$, $\frac{5}{205}$, in the Cabinet), west of Gen. Hall's marble quarry, it is of a bluish color exceedingly like the Plymouth brecciated marble. In Rutland immediately overlying the western range of the quartz rock, there is a limestone apparently brecciated, and remotely resembling the previous specimen. Both are from the western limits of the same group of limestone. The latter as it lay in rough blocks upon the side of the road appeared like certain highly fossiliferous rocks that we had seen upon the shores of Lake Champlain. We are not sure but the convoluted ridges and depressions of this rock, becoming more prominent by exposure, may be fucoids. Geodic masses an inch or two in diameter are frequent in it also, producing many of the ridges. Micaceous films sometimes surround the geodic masses. The general color is a dark bluish gray. The fragments of the limestone imbedded are of a dark brown color. The bed is from forty to fifty feet thick in the northeast part of Rutland, and probably is at least a mile long. It is on the east road from Rutland to Sutherland's Falls.

In the east part of the limestone, near its northern extremity, a tough, white, brecciated limestone occurs, as at Painesville.

Micaceous limestone usually occurs only at the junction of the limestone and mica schist, and is not very abundant. It frequently resembles gneiss. The best locality of it is in North Adams, Mass., at the excavation for the Hoosac Tunnel. The same variety in Vermont is less marked.

The coloring matters of the limestones are usually derived from minute particles of slaty matter disseminated through them. Hence they never fade or disappear, or change their position in the slabs after they have been quarried. The occasional stains which appear may be produced by a small portion of pyrites, affording a dirty brownish hue. Most of the iron rust stain upon the blocks of marble at the mills is temporarily produced by particles of iron worn from the saws.

Beds of limestone rarely decompose beneath the soil. Water percolates into the joints and enlarges the planes of separation by gradually dissolving portions of the carbonate of lime. This process has been exemplified at the west end of the tunnel, just mentioned, where the work of excavation has been greatly hindered in consequence. The fragments may assume imitative forms; and when particles of mica, etc. are numerous in the rock, the removal of the limestone leaves them prominently upon the surface.

III. MAGNESIAN LIMESTONES AND DOLOMITES.

It is not always easy to distinguish dolomites from limestones by external appearances. The chief distinctions are these: 1st, The texture of a dolomite is less firm than that of pure limestone; so much so that it may crumble into sand. 2d, Dolomite is less distinctly stratified than pure limestone. The great mass of dolomite in the red sandrock group illustrates this distinction more forcibly than the dolomites of the present group. 3d, When pure limestone in the state of powder is mixed with nitric acid, it dissolves rapidly, with powerful effervescence; so that in a few moments, if enough acid has been added, nothing remains undissolved except the earthy residuum. But dolomite does not effervesce so briskly, hardly showing any agitation, and yet requiring a long time for its complete solution. When carbonate of lime is mixed with dolomite, both actions are seen; but the first is speedily accomplished, and the second continues to act for a long time as before. In many cases, however, only a careful analysis will decide the character of the rock. The annexed table gives the analysis of all the dolomitic Eolian limestones that have been made for the Survey:

Locality.	Silica and insoluble subst'ces.	Alumina & Perox'd of Iron.	Carbonate of Lime.	Carbon'te of Magnesia.	Water and Loss.	Total.
Limestone, Bristol,	1.40	2.00	51.35	44.76	.49	100.00
Brecciated limestone, Bristol,	3.9	3.8	51.7	40.6		100.0
Water limestone, Shelburne,	11.40	2.65	48.85	36.84	.70	100.44
Yellowish limestone, Brandon,	3.44	carb. iron. 3.67	40.88	51.40		99.39

Thus, generally, these varieties are either a double carbonate of lime and magnesia, or a carbonate of lime mixed with a large proportion of the double carbonate, and where magnesia exists at all in limestones, it probably exists in combination as a dolomite, the remainder being carbonate of lime or carbonate of magnesia, in excess. The dolomites are generally crystalline, often finely granular and sometimes pulverulent, but rarely compact. They decidedly predominate along the eastern part of the limestone range, and are sometimes interstratified with pure limestone. It is a noticeable fact that the pure limestones abound at the western edge of the deposit, and the dolomites with silicious limestones at the eastern limit. Circumstances were varied at the different periods when the several varieties were produced. We are not certain whether the magnesia was all introduced when the rock itself was produced, or whether the process of alteration in some way has introduced the magnesia.

The dolomite is sometimes fetid, so as to give a strong odor when struck with a hammer. This is usually regarded as proof of the existence of organic matter. Some of the layers of dolomite of this range, in Massachusetts, are flexible when moistened, especially in New Ashford.

IV. & V. CLAY SLATE, TALCOSE SCHIST, TALCOSE LIMESTONE, Etc.

So much clay slate is interstratified with the western belt of the Eolian limestone, that it is impossible to include all the limestone under one color on the map, without including much of the slate with it. This is the case between Fairhaven and the north part of Orwell and Sudbury. The slate is all argillaceous, sometimes slightly argillaceous. It is very remarkable that these slates should entirely disappear and be replaced by limestone.

But elsewhere in Vermont, it is common to find occasional seams of slate interstratified with the limestone. It is the most common north of the slates referred to, but is not entirely wanting in the south part of the formation. The largest amount of slate we have seen at any one locality, is at Weybridge, near the monument of Silas Wright. It must be at least fifty feet thick, and is interstratified with limestone, and is about a mile east of Snake Mountain.

Layers of limestone are often separated from one another by argillaceous films. Often these films become talcose, and even talcose schist. There is scarcely a marble quarry in Vermont where beautifully crystalline seams of talcose schist do not occur. As the marble is delicately white and clear, so the associated schists have a delicately distinct color and are free from foreign minerals. Really, however, the schists appear like the impurities of the marble collected together at intervals: as if the Maker of the marble had formed it on purpose for man's use. With these schists limestone, more or less talcose, is associated in small quantities. Specimens of some of these varieties may be seen in Nos. $\frac{5}{192}$, $\frac{5}{203}$, $\frac{7}{116}$, $\frac{7}{119}$, $\frac{7}{120}$, and $\frac{8}{77}$, in the State Cabinet.

VI. QUARTZOSE LIMESTONES, AND BEDS OF QUARTZ.

Under this head we include all beds of pure silicious matter, and those varieties of silicious limestone of which more than half are silica. Of pure layers of quartz good examples are found in Bennington, Manchester, Cornwall and Shoreham. Between the villages of East Bennington and Bennington the quartz shows itself—both upon the plain and upon the hill. The rock is undistinguishable from the usual variety of the quartz formation. The strata are about two feet thick. At Rich's village in Shoreham the layer of quartz occupies the lower portion of the valley, and is about eight feet thick. Other similar layers occur to the east both in Shoreham and Cornwall. Beds of quartz rock are found in the Eolian limestone at Factory Point in Manchester.

Perhaps the range of quartz rock from Chittenden to Danby ought to be considered as a part of the limestone, as it is interstratified with it.

Much of the limestone immediately bordering upon the quartz rock is a calcareous quartz rock. But the silica and carbonate of lime must be regarded as mixtures and not chemical combinations. So silicious are some of these varieties that some have called them quartz rock, as along the eastern boundary of the limestone from Dorset to Danby and W. Clarendon. At the latter place there is a calcareous sandstone interstratified with the limestone, very much like some varieties of Potsdam sandstone except that the cement of the grains of sand is calcareous. At West Dorset, in the great valley of the mountains and also near the village, there is a red quartzose limestone, appearing as if it had been severely heated.

Another rock containing scarcely any carbonate of lime may be seen a few rods east of the railroad in East Dorset, and northerly through the town for nearly four miles. It is a black argillaceous rock decomposing into a soft black sand. It is hence composed of quartz, argillaceous matter and limestone. We have sometimes conjectured whether this bed might not be a means of identifying the same layers of limestone at different localities in the same way as fossils. It is situated very near the top of the limestone next to the quartz. Similar beds of rock are the various dark colored and brecciated limerocks adjoining elsewhere the slate or quartz, as upon Mt. Eolus, Wallingford, Rutland, etc.—The resemblance, however, is slight.

Divisional Planes.

The divisional planes in this group are abundant, though not as numerous as in many rocks. Yet very few observations have been made respecting them. This department has been greatly neglected in the field work of the survey.

Near the west line of Cornwall there is a large ledge of coarse brown limestone, having a dip from 45°–70° W. In it are three sets of jointed planes: N. 45° E., dipping 65° E.; N. 60° W., perpendicular; and N. 45° W., dipping 75° W. At Adair's marble quarry, in South Wallingford, where the strata dip 57° W., joints dip 20° E., which might be mistaken for strata by inexperienced eyes, as they are generally about three feet apart, and are of great assistance to the quarrymen. In Danby Corners the joints dip 40° N. W. At Hitchcock's marble quarry, near Clarendon Springs, the joints run N. and S., and dip from 60° to 65° E. (A. D. H.) As a general fact, it may be stated that jointed planes cross the strata nearly at right angles to the dip and strike. Where several systems traverse the strata, rhombohedral or rectangular blocks are formed. One of the best examples of these rocks is in North Dorset, near a curious dike of lithomarge. The blocks are rectangular, and are much employed for building purposes, being already prepared by nature for the mason's hands.

Cleavage planes occasionally may be seen in the limestone, but not commonly. At Arlington, about two miles west of the railroad station, where the limestone dips 5° E., the cleavage planes dip 25° E. In this case the rock is cleft by numerous seams. And in one of the marble quarries near the village of Arlington, there are indications of a structure resembling cleavage, without any disposition to split in the direction of the *streaks*, more than in any other. The strata dip 4° N.E., while these markings dip 25° N.W. They correspond best with planes of lamination in distinction from the strata. That would make it necessary to suppose that marble was formed precisely as sandstones—a deposition of foreign materials mechanically over a slope. This is a unique case, and we are not prepared to indicate its precise nature. At James Grove's house, in Weybridge, the strata dip 10° E., while the cleavage planes dip 40° E.

STRIKE AND DIP OF THE STRATA.

SOUTHERN TERRAIN.

Locality.	*Strike.*	*Dip.*	*Observer.*
North Adams, Mass., Tunnel,		0°–45° W.,	C. H. H.
North Adams,		20°–40° E.,	C. H. H.
North Adams, Natural Bridge,		10° E.,	C. H. H.
Pownal, Massachusetts line,	N. 5° W.,	30° E.,	C. B. A.
Pownal, south part,	N. 10° E.,	20° E.,	C. B. A.
Pownal, west part,	N. 80° E.,	14° N.,	C. B. A.
Pownal, north part,	N. 10° W.,	20° E.,	C. B. A.
Pownal, east part,	About N. and S.,	25° E.,	C. H. H.
Pownal, north part,		About S.W.,	C. H. H.

Locality.	*Strike.*	*Dip.*	*Observer.*
Pownal, north part,	N. 25° E.,	10° E. and 10° W.,	A. D. H.
Bennington, south part,	N. 20° E.,	Dip west,	A. D. H.
East Bennington, north of village,	N. 70° E.,	20° S.E.,	C. H. H.
East Bennington, west of village,	N. 43° W.,	15° S.W.,	C. H. H.
Bennington, west of do.,	N. 43° W.,	25° S.W.,	C. H. H.
Mount Anthony, foot,	N. 85° E.,	5°–7° S.W.,	C. H. H.
Bennington, Hubbell's quarry,	N. 12° W.,	15° W.,	C. H. H.
Bennington, west part,		Dip west,	C. H. H.
Bennington, west line,	N. 10° E.,	55° E.,	C. H. H.
North Bennington,	N. 5° E.,	10° E.,	A. D. H. and C. H. H.
Shaftsbury, southeast part,	N. 3° E.,	10° W.,	A. D. H.
Shaftsbury, west part, near line,		Dip east,	C. H. H.
Shaftsbury, Cranston's quarry,	N. and S.,	10° E.,	A. D. H.
Shaftsbury, east of center,	N. and S.,	10° E.,	A. D. H.
Shaftsbury, west of center,		Dip west,	C. H. H.
Shaftsbury, west of center,	N. 15° E.,	25° E.,	C. H. H.
Shaftsbury, depot,	N. and S.,	10°–12° W.,	C. H. H.
Shaftsbury, east of depot,	N. and S.,	Dip west,	A. D. H.
Shaftsbury, northeast part,	N. and S.,	10° E.,	A. D. H.
East Arlington,	N. 13° E.,	45° E.,	C. H. H.
Arlington, west of do.,	N. 13° E.,	22° E.–0°,	C. H. H.
Arlington, center,		Horizontal,	C. H. H.
Arlington, West & Canfield's old quarry,	E. and W.,	16° S.,	A. D. H.
Arlington, north of do.,	N. and S.,	20° E.,	A. D. H.
Arlington, West & Canfield's,	N. 45° E.,	45° N.W.,	A. D. H.
Arlington, O. & A. D. Canfield's,	N. and S.,	Average 20° W.,	A. D. H.
Arlington, do. south quarry,	N. and S.,	8° E.,	C. H. H.
Arlington, do. north quarry,	N. and S.,	5° E.,	C. H. H.
Arlington, do., a slide,		38° E.,	C. H. H.
Arlington, do., at their mill,	N. and S.,	4° W.,	C. H. H.
Arlington,	N. 5° E.,	20° E.,	A. D. H.
Arlington, McKee's quarry,		About horizontal,	A. D. H.
Arlington, west of do.,	N. 5° E.,	15° W.,	A. D. H.
Arlington, east of do.,	N. 5° E.,	40° E.,	A. D. H.
West Arlington,		5° W. and 25° E., (?)	C. H. H.
Arlington, east part,	N. 10° E.,	15° E.,	A. D. H.
Manchester, southwest part,	N. 25° E.,	32° W.,	A. D. H.
Manchester, southwest of village,	N. 25° E.,	40° W.,	A. D. H.
Manchester, Factory Point,	N. and S.,	12° W.,	A. D. H. and C. H. H.
Manchester, Factory Point,		Horizontal,	C. H. H.
Manchester, north part,	N. 5° E.,	20° E.,	C. B. A.
Manchester, top of Taconic range of mountains,		About 10° E.,	E. H. and C. H. H.
Dorset, south and east parts,	N. and S.,	Dip east and west,	C. B. A.
Dorset, Holley's quarry,	N. 30° E.,	30° W.,	A. D. H.
Dorset, R. P. Bloomer's quarry,	N. 30° E.,	10° W.,	A. D. H.
Dorset, Way, Wilson & Sandford's quarry,		Horizontal,	A. D. H.
Dorset, south of Dorset Mountain,		10°–12° N. and N.E.,	A. D. H. and C. H. H.
Dorset, east line,	N. 20° E.,	65°–85° E.,	C. H. H.
East Dorset,	N. 50° W.,	15° N.E.,	C. H. H.
Mount Eolus, east slope,		10° N.W. to S.E., 8° W.,	C. H. H.
Mount Eolus, Holley, Field & Kent's,		Horizontal,	A. D. H. and C. H. H.
Mount Eolus, Cave Quarry,		8° W.,	C. H. H.

Locality.	*Strike.*	*Dip.*	*Observer.*
Mount Eolus, west side,	N. 20° E.,	24° E.,	E. H. and C. H. H.
Mount Eolus, north side,	N. 10° W.,	10° N.,	C. H. H.
Mount Eolus, northwest side,	N. 30° W.,	10° S.W.,	C. H. H.
West Dorset,	N. 85° E.,	14° S.,	C. H. H.
Mount Eolus, notch on west side,		Dip east,	C. H. H.
West Dorset, north of village,	N. 30° E.,	20° S.E.,	C. H. H. and E. H., jr.
East Dorset, north of village,		Dip northerly,	C. H. H.
North Dorset,	N. and S.,	12° E.,	C. B. A.
North Dorset,	N. and S.,	17° E.,	C. H. H.
Danby, southeast part,	N. 10° W.,	10° W.,	C. B. A.
Danby, Griffith's quarry,	N. 45° W.,	10° S.E.,	E. H., jr.
Danby, Symington's do.,	N. 45° W.,	16° S.E.,	E. H., jr.
Danby, Blake & Barney's do.,	N. 45° W.,	30° S.E.,	E. H., jr.
Danby, Fish's quarry,	N. 60° W.,	15° S.E.,	E. H., jr.
Danby, Barnes' quarry,	N. 40° W.,	45° S.E.,	E. H., jr.
Danby, Barneyville,	N. 20° E.,	17° E.,	A. D. H.
Danby Corners,	N. 20° E.,	60° E.,	C. H. H.
Danby, north of Corners,	West of north,	0°–10° N.E.,	C. H. H.
Danby, north of Corners,	N. 60° E.,	60° S.E.,	C. H. H.
Danby, north part,	East of north,	10° E.,	C. H. H.
Danby, near D. Borough,	E. and W.,	25° S.,	C. B. A.
Danby, northeast corner,	N. and S.,	Dip west,	C. B. A.
Danby, northeast part,	N. 30° E.,	25° W.,	C. B. A.
South Wallingford,	N. 10° E.,	60° E.,	C. B. A.
Wallingford, westerly part,	N. 10° E.,	70° W.,	C. B. A.
South Wallingford, A. Warner's quarry,	N. 30° E.,	65°–80° W.,	A. D. H.
South Wallingford, Adair's quarry,	N. 30° E.,	40°–72° W.,	A.D.H., E.H., jr., C.H.H.
South Wallingford, northeast of do.,	N. 20° E.,	53° W.,	E. H. and C. H. H.
South Wallingford, west of quarries,		55° W.,	A. D. H.
South Wallingford, Hall's quarry,	N. 15° E.,	60° W.,	A. D. H.
South Wallingford, west of do.,	N. 15° E.,	40° W.,	A. D. H.
Wallingford, west part,	N. 30° W.,	60° S.W.,	A. D. H.
Wallingford, west part,	N. 20° W.,	64° S.W.,	E. H., jr.
Wallingford, east of do.,	N. 30° E.,	65° E.,	A. D. H.
Wallingford, near do.,	N. 20° E.,	80° E.,	A. D. H.
Wallingford, one mile south of N. Wallingford,	N. 15° E.,	Dip west,	A. D. H. and E. H., jr.
North Wallingford,		Dip north,	C. H. H.
Mt. Tabor, west part,		Dip east,	C. H. H.
Mt. Tabor, southwest corner,	N. 5° E.,	10° E.,	A. D. H.
Tinmouth, west of pond,	N. 20° E.,	80° W. and 90°,	C. H. H.
Tinmouth, west of pond,	N. 20° E.,	65°–75° W.,	A. D. H.
Tinmouth, south part,	N. & S., and N. 45° E.,	20° W. and 30° S.W.,	A. D. H.
Tinmouth, south part,	N. and S.,	40° W.,	A. D. H.
Tinmouth, southeast from center,	N. 10° E.,	40° W.,	A. D. H.
Tinmouth, near center,	N. 10° E.,	65° W. and 20° W.,	A. D. H.
Tinmouth, near center,	N. 10° E.,	40° W.,	A. D. H.
Tinmouth, near center,		15° W.,	C. H. H.
Tinmouth, north of center,	N. 20° E.,	30° W.,	A. D. H.
Tinmouth, gorge in Taconic range,		Dip east,	E. H. and C. H. H.
Tinmouth, north part,	N. 20° E.,	38° W.,	A. D. H.
Tinmouth, northwest part,		Nearly horizontal,	E. H. and C. H. H.
Tinmouth, north part,	N. 20° E.,	20°–25° W.,	A. D. H.

Locality.	*Strike.*	*Dip.*	*Observer.*
Clarendon, southwest part,	N. 25° E.,	20° W.,	A. D. H.
Clarendon, west part, A. H. Colvin's,	N. 30° E.,	40° W.,	A. D. H.
Clarendon, west part,	N. and S.,	10° E.,	A. D. H.
Clarendon, north of Springs,	N. and S.,	20° E.,	A. D. H.
Clarendon, Hitchcock's quarry,	N. 10° E.,	42° W.,	A. D. H. and C. H. H.
Clarendon, near Springs,	N.E. and S.W.,	A curve in strata, 22° N.W. & 30° S.E.,	A. D. H.
Clarendon, Chippen Hook,	N. and S.,	40° W.,	A. D. H.
Clarendon, north part,	N. and S.,	40° E.,	A. D. H.
Clarendon, west part,		50° E.–90°,	C. H. H.
Clarendon, south part,	West of north,	25° W.,	A. D. H.
Clarendon, Mill River,	N. 20° E.,	40° W.,	A. D. H.
Clarendon, center,		Dip west,	C. H. H.
Clarendon, east part,	N. 20° E.,	55° E.,	A. D. H.
Clarendon, east part,	N. 20° E.,	85° W.,	A. D. H.
Clarendon, Rutland line,	N. 30° E.,	42° W.,	C. H. H.
Rutland, southwest corner,	N. 10° E.,	40° E.,	A. D. H.
Rutland, Hyde's quarry,	N. 30° W.,	45° E.,	A. D. H.
Rutland, Hyde's quarry,	N. 30° W.,	35° E.,	E. H. and C. H. H.
Rutland, west of do.,	N. 20° W.,	25° E.,	A. D. H.
Rutland, do.,	N. 10° W.,	28° E.,	E. H. and C. H. H.
Rutland, north of do.,		40° E.,	A. D. H.
West Rutland, west of the quarries,	N. 10° W.,	25° E., 40° E. and 45° E.,	A. D. H.
West Rutland, Sierman & Holley's,	N. 10° W.,	22° E.,	A. D. H.
West Rutland, Sheldon & Slason,	N. 10° W.,	45°–50° E.,	A. D. H. and E. H., jr.
West Rutland, Sheldon & Slason,	N. 30° W.,	40° E.,	C. H. H.
West Rutland, Rutland Marble Co.,	N. 15° E.,	35°–50° E.,	E. H., jr. and A. D. H.
Rutland, A. & Adams,		60° E., avg. 55° E.,	A. D. H.
Rutland, W. Vt. Co.,	N. and S.,	24° E.,	E. H., jr.
Rutland, Parker's,	N. 15° W.,	70° E.,	E. H., jr.
West Rutland, Sheldon & Slason's, north part,	N. and S.,	55°–65° E.,	E. H., jr.
Rutland, north part,	N. 20° W.,	Dip east 40°,	A. D. H.
Rutland, northwest part,	About N. and S.,	15° E., 10° E., 25° E., 20° E.,	A. D. H.
Rutland, in some parts of the marble,		Nearly horizontal,	A. D. H.
Rutland, northwest part,	About N. and S.,	40°–60° W.,	A. D. H.
Sutherland's Falls,	N. and S.,	70° W.,	E. H., jr.
Sutherland's Falls,	N. and S.,	75° E.,	C. H. H.
Rutland, one and a half miles north of center,	N. 20° E.,	45° E.,	E. H., jr.
Rutland, west of center,	About N. and S.,	15°–20° E.,	C. H. H.
Rutland, near post-office,		5°–10° E.,	C. H. H.
Rutland, south of Sutherland's Falls,	N. 10° E.,	Dip east,	A. D. H.
Rutland, north of village,		10°–15° E.,	C. H. H.
Rutland, near east line,	East of north,	45° E.,	C. H. H.
Pittsford, southwest part,	N. 10° W.,	30° E.,	A. D. H.
South Pittsford,		22° E.,	E. H., jr.
Pittsford, H. C. Powers' land,	N. 60° W.,	10° N.E.,	A. D. H.
Pittsford, southwest part,	N. 10° W.,	20° E.,	A. D. H.
Pittsford, west part,	N. 5° E.,	15° W. and 10° E.,	A. D. H.
Pittsford, west part,	N. 10° W.–N. 10° E.,	10°–15° E.,	A. D. H.
Pittsford, middle part,	N. 10° W.,	20° E.,	A. D. H.
Pittsford, east part,	N. 5° E.,	65° E.,	C. H. H. and E. H., jr.
Pittsford, north part,	About N. and S.,	70° E.,	C. H. H. and E. H., jr.
Pittsford, east part,	N. and S.,	35° E.,	C. B. A.

Locality.	*Strike.*	*Dip.*	*Observer.*
Pittsford, near Furnace,	N. and S.,	75° E.,	C. B. A.
Pittsford, foot of Bald Mountain,	N. 60° W.,	80° W.,	C. H. H.
Pittsford, Sugar Hollow River, north part,	N. 10° E.,	55° E.,	C. H. H.
Chittenden, Cave, northwest part,	N. 15° E.,	39° E.,	C. H. H.
Chittenden, west of Cave,		50° E.,	C. H. H.
Chittenden, Furnace River, north part (Tower),	N. 20° E.,	90°,	C. H. H.
Brandon, west part,	East of north,	20° E.,	C. H. H.
Brandon, one mile west of village,	N. 20° E.,	20° W.,	C. H. H.
Brandon, Austin's quarry,	N. and S.,	50° E.,	C. H. H.
Brandon, Selden's mill,	N. 4° E.,	80° E.,	C. H. H.
Brandon, southwest corner,	N. 7° E.,	60° E.,	C. B. A.
Brandon, southwest part,	N. and S.,	64° E.,	C. B. A.
Brandon, middle part,	N. and S.,	44° E.,	C. B. A.
Brandon, middle part,	N. and S.,	50° E.,	C. B. A.
Brandon, east part,	N. 15° E.,	35° E.,	C. B. A.
Salisbury, half a mile south of village,	N. and S.,	35° E.,	C. A. W.
Leicester, east part,	N. 10° W.,	45° E.,	C. H. H.
Leicester, Whiting station,		Great curves in limestone,	C. H. H.
Whiting, south part,		3° S.E.,	C. H. H.
Middlebury, middle part,	N. 20° E.,	36° W.,	C. H. H.
Middlebury, near center,	N. 20° E.,	Irregular—nearly horizontal,	A. D. H. and C. H. H.
Middlebury, north of center,	N. 10° E.,	50°–80° E.,	A. D. H. and C. H. H.
Middlebury, north of center,	N. 10° E.,	25° E.,	A. D. H. and C. H. H.
Middlebury, Cornwall line,	N. 30° E.,	30° E.,	A. D. H. and C. H. H.
Middlebury, northwest of center,	N. 10° W.,	25° E.,	E. H. and 3 assistants.
Middlebury, Cornwall line,	N. 15° E.,	50° E.,	C. B. A.
Middlebury, southwest part,	N. 10° W.,	25° E.,	C. B. A.
Middlebury,	N. and S.,	30° E.,	C. B. A.
Middlebury, middle part,	N. and S.,	82° W.,	C. B. A.
Middlebury, middle part,	N. 5° E.,	36° E.,	C. B. A.
Middlebury, south part,	N. 15° E.,	28° W.,	C. B. A.
Middlebury, south part,	N. and S.,	60° E.,	C. B. A.
Middlebury, northwest corner,	N. and S.,	18° E.,	C. B. A.
Middlebury, north part,	N. 10° W.,	62° E.,	C. B. A.
New Haven, southwest corner,	N. and S.,	30° E.,	C. B. A.
New Haven, middle part,	N. and S.,	17° E.,	C. B. A.
New Haven, west part,	N. 20° E.,	45° E.,	C. H. H. and E. H., jr.
New Haven, south of center,		Dip east,	C. H. H. and E. H., jr.
New Haven, south of center,	N. 10° E.,	40° E.,	C. H. H. and E. H., jr.
New Haven, east part,	East of north,	25°–35° E.,	C. H. H.
New Haven, east of depot,	About N. and S.,	25° W.,	C. H. H.
New Haven, northwest part,		Dip 25°–30° E.,	C. H. H.
Weybridge,	N. 10° W.,	40° E.,	E. H., etc.
Cornwall, north part,	N. 25° W.,	24° E.,	C. B. A.
Cornwall, west part,	N. 35° W.,	50° N.E.,	C. B. A.
West Cornwall, quarry,		10° E.,	C. H. H.
Cornwall, east part,	N. and S.,	Dip east,	C. B. A.
Cornwall, center,	N. 40° E.,	28° N.W.,	A. D. H. and C. H. H.
Cornwall, center,	N. 10° E.,	25° E.,	A. D. H.
Cornwall, west line,	N. 10°–20° E.,	45°–72° W.,	A. D. H. and C. H. H.
Orwell, east of village,	N. 20° E.,	30° E.,	C. H. H.
Orwell, east of village,	N. 15° E.,	30° E.,	C. H. H.

Locality.	*Strike.*	*Dip.*	*Observer.*
Orwell, east part,	N. 45° E.,	3° S.E.,	C. H. H.
Orwell, east line,	N. 20° E.,	50° E.,	C. H. H.
Sudbury, west part,	N. 20° E.,	33° E. and 13° E.,	C. H. H.
Sudbury, marble,		Mostly horizontal,	A. D. H.
Sudbury, south marble quarry,	N. and S.,	25° E.,	A. D. H.
Sudbury, church,		23° N.E.,	C. H. H.
Sudbury, east of church,	East of north,	7° E. and 30° E.,	C. H. H.
Sudbury, east line,	N. 40° E.,	30° S.E.,	C. H. H.
Orwell, southeast corner,	N. 10° E.,	25° E.,	A. D. H.
Subbury, west part,	N. 10° E.,	24° E.,	C. B. A.
Fairhaven, northeast part,	N. and S.,	45° E.,	C. B. A.
Bristol, west part,		15° E.,	C. H. H.

NORTHERN TERRAIN.

Monkton, northeast part,		Dip E. and W.,	C. H. H.
Hinesburgh, southeast part,		Dip east,	C. H. H. and E. H., jr.
Hinesburgh, east part,	N. 20° E.,	15° E.,	A. D. H.
Hinesburgh, east part,	N. 10° E.,	22° E.,	C. H. H.
Hinesburgh, west of center,	N. 35° E.,	25° W.,	C. H. H.
Hinesburgh, northwest part,	N. and S.,	30° E.,	C. B. A.
Hinesburgh, northwest part,	N. and S.,	52° E.,	C. B. A.
Hinesburgh, northwest part,	N. and S.,	36° W.,	C. B. A.
Hinesburgh, south of center,	N. 10° E.,	20° E.,	A. D. H.
Shelburne, east part,	N. and S.,	30° E.,	C. B. A.
Shelburne, north part,	About N. and S.,	40° E.,	C. H. H.
Shelburne, "Parian marble quarry,"	N. & S. to N. 5° E.,	75°–78° E.,	A. D. H.
Burlington, south line,	N. and S.,	40° E.,	A. D. H.
Burlington, south of Natural Bridge,	N. 10° E.,	20° E.,	A. D. H.
Burlington, southeast corner,	N. 10° W.,	28° E.,	C. B. A.
Burlington, southeast part,	N. and S.,	30° E.,	C. B. A.
Burlington, east part,	N. and S.,	38° E.,	C. B. A.
Burlington, southeast part,	N. and S.,	35° E.,	C. H. H.
Burlington, east of Vermont University,	About N. and S.,	15° E.,	C. H. H.
Burlington, northeast part,		Dip west,	C. H. H.
Burlington, on Winooski River,	N. and S.,	20° E.,	C. B. A.
Colchester, Penniman's,	N. 10° E.,	15° E.,	A. D. H.
Colchester, west of do.,		18° E.,	Z. T. and C. H. H.
Colchester, Bates' quarry,		4°–5° E.,	C. H. H.
Colchester depot,		Horizontal,	C. H. H.
Painesville, at Hubbell's Falls,	East of north,	Average 10° E.,	C. H. H.
Painesville, at Hubbell's Falls,	East of north,	Varies to 90°,	E. H. and C. H. H.
Colchester, north line,		0°, and dip S.W.,	C. H. H.
Milton, southeast part,	N. 15° W.,	Dip west,	C. H. H.
Milton Falls,		90°, (?)	C. H. H.

In order to facilitate the investigation of the position of the Eolian limestones of Western Vermont, we will reduce the table of dip and strike to another table, showing every few miles the position of the strata in each of the three ranges, in the line of an east and west section crossing them. The western belt, running south from Cornwall to Fairhaven, will be noticed separately. We commence at the southern part of the State, proceeding northerly. The western range of the first section is in Petersburgh, N. Y., but on all the other sections it is in Vermont. Often the middle and east ranges are united into one. In such cases, the eastern range is marked *wanting*, as both are united into one.

Locality.	*West Range.*	*Middle Range.*	*East Range.*
South Pownal,	Dip east,	Dip east,	Dip east.
North Pownal,	Dip east,	Dip east generally,	Wanting.
South Bennington,	Dip east,	Dip west,	Wanting.
North Bennington,	Dip east,	Anticlinal,	Wanting.
Shaftsbury, middle,	Dip east,	Dip west generally ; to E. in S. part of town.	In quartz rock dip east.
Arlington (Section III),	Dip east,	Anticlinal,	Wanting.
Manchester,	Dip east,	Anticlinal,	Wanting.
South Dorset,	Dip southeast,	Synclinal & anticlinal,	Wanting.
North Dorset,	Dip east,	Dip east and northeast,	Wanting.
Danby and Mt. Tabor,	Dip east,	Dip east,	Wanting.
Tinmouth and Wallingford,	Dip west,	Anticlinal,	Wanting.
South Clarendon,	Dip west,	Anticlinal,	Wanting.
North Clarendon,	Anticlinal,	Dip east,	Synclinal.
Rutland, both N. & S. parts,	Dip east,	Dip east,	Dip east.
Pittsford and Chittenden,	Dip east,	Sharp synclinal, mostly dip east,	Dip east.
Brandon,	West & middle united,	Generally dip east,	Dip east.
Whiting and Leicester,	West & middle united,	Generally dip east,	Dip east.
Cornwall and Salisbury,	West & middle united,	Generally dip east,	
Middlebury,	All ranges united in one	Dip E., with numerous local variations,	Probably an inverted axis.
New Haven,	Synclinal and anticlinal	Dip east,	Wanting.
Hinesburgh,	Wanting,	Anticlinal,	Wanting.
Shelburne,	Wanting,	Dip east,	Wanting.
Burlington and Williston,	Wanting,	Dip east, with local anticlinal,	Wanting.
Colchester,	Wanting,	Dip east,	Wanting.
Milton,	Wanting,	Dip east,	Wanting.

The strata dip east generally in the whole of the belt of limestone in the towns of Cornwall, Whiting, Shoreham, Sudbury, Hubbardton, Benson, and Fairhaven. Local exceptions occur in a few places. Probably most of the strata increase their amount of inclination as we penetrate into the earth. Examples of this sort can be seen in Sheldon & Slason's quarry in West Rutland, where the dip increases as much as 10°; and north of Middlebury village, where the inclination increases 40° in a few feet of depth.

There is so much importance attached to this subject, that we give upon Plate VIII, Fig. 2, an enlarged map of the peculiarly disturbed region between Pittsford and Dorset. This figure shows what sort of a geological map is needed for the whole State. Every slight variation in the dip should be noticed, and the dip and strike, also, for every square half mile, or oftener. Not merely the position of the Eolian limestone, but also of the slate, quartz rock, and conglomerate. And they should be considered topographically.

It will be observed that the position of the limestone is not uniformly the same. For example, the limestone adjoining the talcoid schists dips west in the south part of Dorset, east in the north part, southwest in the southwest part of Danby, east in the north part of Danby, west through most of Tinmouth, mostly west in Clarendon; then it is interrupted by a band of slate. Passing by this interruption, from West Rutland to Brandon the dip is uniformly to the east. Similar variations may be noticed along the east border of the Eolian limestone, adjoining the quartz rock. Similar facts appear upon examining the

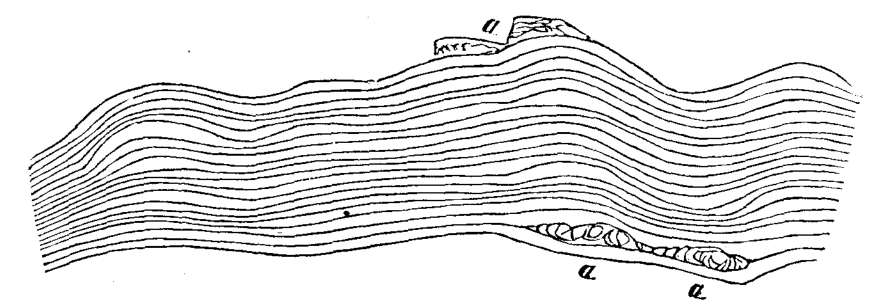
connections of the limestones with the middle range of quartz rock, etc. Consequently it is extremely difficult to become satisfied respecting the true relations of the Eolian limestones to the adjacent rocks.

Two faults are evident in the limestone: one north of Danby Mountain, showing that the whole of Danby Mountain and Mt. Eolus have been raised up bodily, and in West Rutland. The latter case is made evident by the sudden change of the marble from one side of the valley to the other, and is probably connected with the gap in the Taconic range of mountains, to the west.

The schists upon the top of Danby Mountain must have been once connected with those in Danby, north of the fault; and probably the limestone is newer than the quartz rock. Hence there must be another fault between the Eolian limestone and the quartz rock. From the relations of the limestone to both the quartz rock and schists, one would think the latter were identical, in examining the region about Mt. Eolus.

Several local sections and variations in dip demand notice. First we present a section (Fig. 260), drawn by Professor Adams, to represent the undulations of this limestone in Middlebury. The ledge represented is thirty feet long. *a, a, a,* represent concretionary masses of limestone.

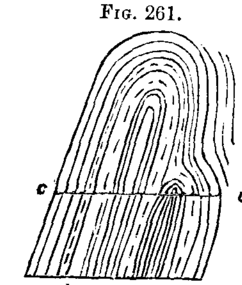
Fig. 260.



Plicated Limestone in Middlebury.

Fig. 261 represents two minor folds in a general fold at White & Higgins' marble quarry at Whiting Station, in Leicester. The width of the whole fold is forty rods, and it may be traced a considerable distance north and south, as it constitutes a hill. In the figure, *a, a,* represent blue marble; the interior of the folds, surrounded by sparry seams, *b, b,* of thick-bedded strata. The remainder are mostly marble, of various colors, striped or variegated, whereby the same layer may be readily traced upon both sides of the anticlinal. The small folds are three feet across.

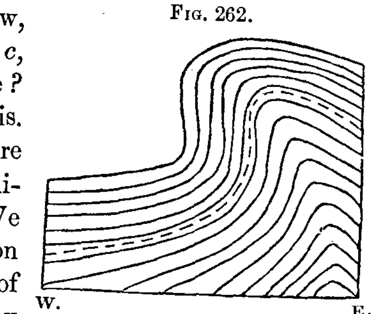
Fig. 261.



Inverted Anticlinal.

This figure suggests an important topic to be well considered in the geology of the whole State: the limestone dips in the same direction upon both sides of the fold. We know of the existence of the fold only because the top of it has not been worn away. Suppose, now, that the fold should be worn down to the line *c, c,* what evidence should we have had of its existence? Merely the correspondence of the layers upon the different sides of the axis. And in metamorphic rocks, where essentially the same kind of minerals are found in almost every layer, it would be very difficult, without the most tediously thorough examination, to discover these inverted anticlinals. We suspect the presence of several of these anticlinals in this limestone formation where there is little evidence of them; particularly between the limestones of Brandon and Sudbury, upon Section VII. If this is so, then there may have been a fold between the whole western spur and the principal range, inclosing most of the slates and schists. And in such cases the rocks may be somewhat different upon the different sides of the anticlinal in consequence of different degrees of metamorphism.

Fig. 262.



Fold near Clarendon Springs.

This principle would be a useful one to employ, where it is possible, in the solution of the problem of the thickness of the other metamorphic rocks.

REPORT

ON THE

GEOLOGY OF VERMONT:

DESCRIPTIVE, THEORETICAL, ECONOMICAL,

AND

SCENOGRAPHICAL;

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all the other sections it is in Vermont. Often the middle and east ranges are united into one. In such cases, the eastern range is marked *wanting*, as both are united into one.

Locality.	*West Range.*	*Middle Range.*	*East Range.*
South Pownal,	Dip east,	Dip east,	Dip east.
North Pownal,	Dip east,	Dip east generally,	Wanting.
South Bennington,	Dip east,	Dip west,	Wanting.
North Bennington,	Dip east,	Anticlinal,	Wanting.
Shaftsbury, middle,	Dip east,	Dip west generally; to E. in S. part of town.	In quartz rock dip east.
Arlington (Section III),	Dip east,	Anticlinal,	Wanting.
Manchester,	Dip east,	Anticlinal,	Wanting.
South Dorset,	Dip southeast,	Synclinal & anticlinal,	Wanting.
North Dorset,	Dip east,	Dip east and northeast,	Wanting.
Danby and Mt. Tabor,	Dip east,	Dip east,	Wanting.
Tinmouth and Wallingford,	Dip west,	Anticlinal,	Wanting.
South Clarendon,	Dip west,	Anticlinal,	Wanting.
North Clarendon,	Anticlinal,	Dip east,	Synclinal.
Rutland, both N. & S. parts,	Dip east,	Dip east,	Dip east.
Pittsford and Chittenden,	Dip east,	Sharp synclinal, mostly dip east,	Dip east.
Brandon,	West & middle united,	Generally dip east,	Dip east.
Whiting and Leicester,	West & middle united,	Generally dip east,	Dip east.
Cornwall and Salisbury,	West & middle united,	Generally dip east,	
Middlebury,	All ranges united in one	Dip E., with numerous local variations,	Probably an inverted axis.
New Haven,	Synclinal and anticlinal	Dip east,	Wanting.
Hinesburgh,	Wanting,	Anticlinal,	Wanting.
Shelburne,	Wanting,	Dip east,	Wanting.
Burlington and Williston,	Wanting,	Dip east, with local anticlinal,	Wanting.
Colchester,	Wanting,	Dip east,	Wanting.
Milton,	Wanting,	Dip east,	Wanting.

The strata dip east generally in the whole of the belt of limestone in the towns of Cornwall, Whiting, Shoreham, Sudbury, Hubbardton, Benson, and Fairhaven. Local exceptions occur in a few places. Probably most of the strata increase their amount of inclination as we penetrate into the earth. Examples of this sort can be seen in Sheldon & Slason's quarry in West Rutland, where the dip increases as much as 10°; and north of Middlebury village, where the inclination increases 40° in a few feet of depth.

There is so much importance attached to this subject, that we give upon Plate VIII, Fig. 2, an enlarged map of the peculiarly disturbed region between Pittsford and Dorset. This figure shows what sort of a geological map is needed for the whole State. Every slight variation in the dip should be noticed, and the dip and strike, also, for every square half mile, or oftener. Not merely the position of the Eolian limestone, but also of the slate, quartz rock, and conglomerate. And they should be considered topographically.

It will be observed that the position of the limestone is not uniformly the same. For example, the limestone adjoining the talcoid schists dips west in the south part of Dorset, east in the north part, southwest in the southwest part of Danby, east in the north part of Danby, west through most of Tinmouth, mostly west in Clarendon; then it is interrupted by a band of slate. Passing by this interruption, from West Rutland to Brandon the dip is uniformly to the east. Similar variations may be noticed along the east border of the Eolian limestone, adjoining the quartz rock. Similar facts appear upon examining the

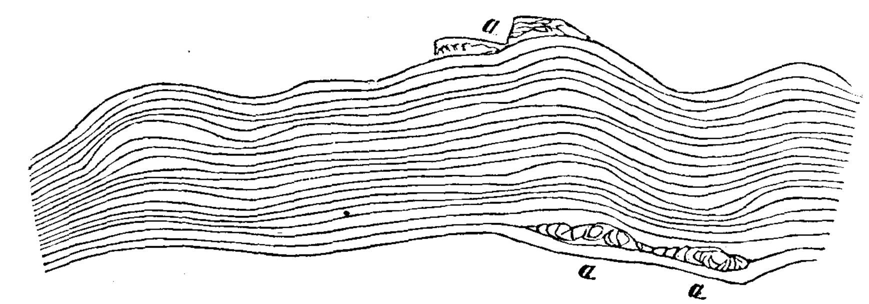
connections of the limestones with the middle range of quartz rock, etc. Consequently it is extremely difficult to become satisfied respecting the true relations of the Eolian limestones to the adjacent rocks.

Two faults are evident in the limestone: one north of Danby Mountain, showing that the whole of Danby Mountain and Mt. Eolus have been raised up bodily, and in West Rutland. The latter case is made evident by the sudden change of the marble from one side of the valley to the other, and is probably connected with the gap in the Taconic range of mountains, to the west.

The schists upon the top of Danby Mountain must have been once connected with those in Danby, north of the fault; and probably the limestone is newer than the quartz rock. Hence there must be another fault between the Eolian limestone and the quartz rock. From the relations of the limestone to both the quartz rock and schists, one would think the latter were identical, in examining the region about Mt. Eolus.

Several local sections and variations in dip demand notice. First we present a section (Fig. 260), drawn by Professor Adams, to represent the undulations of this limestone in Middlebury. The ledge represented is thirty feet long. *a, a, a,* represent concretionary masses of limestone.

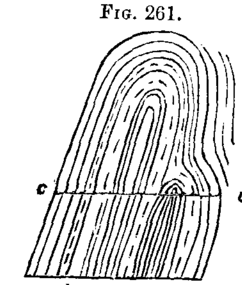
Fig. 260.



Plicated Limestone in Middlebury.

Fig. 261 represents two minor folds in a general fold at White & Higgins' marble quarry at Whiting Station, in Leicester. The width of the whole fold is forty rods, and it may be traced a considerable distance north and south, as it constitutes a hill. In the figure, *a, a,* represent blue marble; the interior of the folds, surrounded by sparry seams, *b, b,* of thick-bedded strata. The remainder are mostly marble, of various colors, striped or variegated, whereby the same layer may be readily traced upon both sides of the anticlinal. The small folds are three feet across.

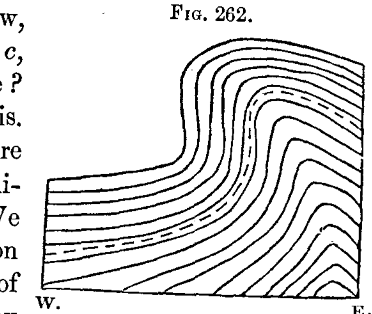
Fig. 261.



Inverted Anticlinal.

This figure suggests an important topic to be well considered in the geology of the whole State: the limestone dips in the same direction upon both sides of the fold. We know of the existence of the fold only because the top of it has not been worn away. Suppose, now, that the fold should be worn down to the line *c, c,* what evidence should we have had of its existence? Merely the correspondence of the layers upon the different sides of the axis. And in metamorphic rocks, where essentially the same kind of minerals are found in almost every layer, it would be very difficult, without the most tediously thorough examination, to discover these inverted anticlinals. We suspect the presence of several of these anticlinals in this limestone formation where there is little evidence of them; particularly between the limestones of Brandon and Sudbury, upon Section VII. If this is so, then there may have been a fold between the whole western spur and the principal range, inclosing most of the slates and schists. And in such cases the rocks may be somewhat different upon the different sides of the anticlinal in consequence of different degrees of metamorphism.

Fig. 262.

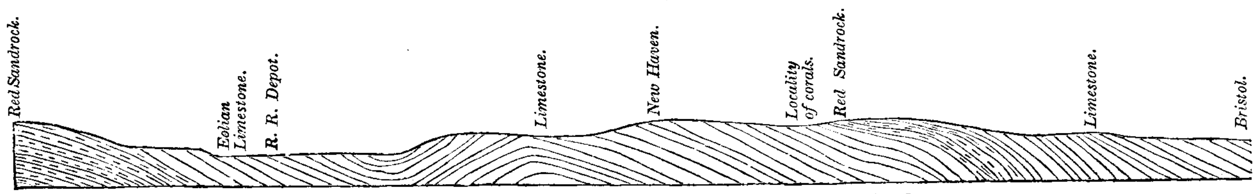


Fold near Clarendon Springs.

This principle would be a useful one to employ, where it is possible, in the solution of the problem of the thickness of the other metamorphic rocks.

We find, occasionally, small folds in the limestone, illustrative of the different forms assumed in anticlinals. The common one is too well known to need a special figure. Fig. 261 represented the inverted anticlinal, and Fig. 262 represents a sharp, rather than inverted, anticlinal near Clarendon Springs, near the seat of great disturbances in the strata. It is rather sharper in nature than in the cut. The limestone is thick-bedded, with one layer a foot thick of quartz rock, marked by a dotted line in the figure. The rock in the vicinity dips east. The ledge from which the cut was derived is eighteen feet long and seventeen feet high, almost extending into the carriage road.

Fig. 263.



Section across the Eolian Limestone in New Haven and Bristol.

Fig. 263 represents the position of the strata across New Haven, from the red sandrock on the west line of the section, to the village of Bristol, on the east, or to the limit of the limestone in that direction. The east end joins directly upon the west end of Fig. 248, under *Quartz Rock*. The limestone near Bristol is of a dolomitic character, or else is ferruginous and silicious. It is rather purer near the first ledge of sandstone and shales about a mile east of New Haven. South of New Haven village the limestone approaches marble in its character, and contains traces of those corals (Stromatopora), that are found more perfect elsewhere. On the west side of the anticlinal, and west of the village of New Haven, the strata are dark colored and much contorted; also containing layers of silicious matter. The rock is thicker bedded and white near the junction of the limestone and red sandrock. In the east part of Waltham the red sandrock and white limestone are seen in juxtaposition, the nearest approximation to a junction of the two that we have found in the whole State. If the two exposures of red sandrock in Fig. 263 are of the same age, the Eolian limestone would seem to form an inverted anticlinal beneath the red sandrock.

Range, Extent and Thickness.

There are two deposits of the Eolian limestones in Vermont. The smaller one is embraced within the limits of Franklin and Chittenden counties, extending from Milton to Hinesburgh. The principal deposit enters the state at Pownal, extends as far north as New Haven, and then curves arouud a deposit of Georgia slate, reaching southerly to Benson. There are numerous branches of this deposit, varying in number in the different parts of its extent. Under the previous head we have classified them into three ranges. We will continue to use this classification, although it is rather artificial.

The eastern range enters the state at Pownal, unites with the middle range in the north part of Pownal, and may perhaps appear again in Bennington and Shaftsbury interstratified with the quartz. The eastern range in Addison county belongs to the middle range properly, and the east range of the south part of the State is probably not found north of Shaftsbury, unless some of the limestones in the quartz rock in Pittsford and Chittenden belong to it.

The middle range enters the State along the valley of Hoosac River in Pownal, and continues, unbroken, constituting the principal part of the deposit, to its termination.

The west range commences on the latitude of Pownal, in Petersburgh, N. Y.; enters the State perhaps in the northwest part of Pownal; is seen on west line of Bennington, in West Shaftsbury, in West Arlington, Sandgate, West Dorset, Danby, Tinmouth; and in

Clarendon separates into two branches; called, upon the table previously given, the west and middle ranges. The eastern branch narrows in the north part of Clarendon, but finally unites with the principal range in Pittsford. The western branch terminates at Rutland line, but is continued after a short interruption, northerly, through the west part of Rutland, uniting with the others in Pittsford. There are six different branches of the Eolian limestone in Pittsford.

The character of this rock in the south part of Pownal is treated of under Section I, as is likewise the case respecting the rocks crossed by the other sections. The limestone is somewhat wider than usual on Hoosac River on account of erosion, and thus it bulges out a little to the west, on the map. The river has been instrumental in wearing away much of the slate rock, and thus increasing the area of the limestone. It does not connect with the limestone of Petersburgh, N. Y.

The valley of the south branch of the Waloomsac River passes over limestone. Near the north line of Pownal, there is a change in the position of the limestone. Instead of overlying the slate it underlies it, as at Mt. Anthony.

In the village of North Bennington the limestone is gray, thick-bedded, and dips at a small angle to the east. About a mile from the State line in the southwest part of Shaftsbury, the west range of limestone shows itself, and probably extends north to connect with the belt of limestone in West Arlington. Cranston's marble quarry is one and a half miles southwest of Shaftsbury Center. Above this quarry there is a black clay slate more or less plumbaginous, interstratified with it. Near Shaftsbury R. R. depot, there are some ledges of thick-bedded limestone dipping only 15° W., appearing as if they had never been disturbed. In the east part of the town there is limestone interstratified with quartz rock, along Furnace Brook. Along the eastern base of the great range of mountains, styled West Mountain, Spruce Peak, Bald Mountain, Red Mountain and Equinox Mountain, limestone and marble are found in great abundance running under the range, and consequently dipping to the west. The great valley east is underlaid by limestone, and seems to have been excavated because the limestone decomposes more easily than the adjacent firm slates or unyielding quartz.

There is nothing of special interest north of Section III. until reaching Factory Point in Manchester. There, in the bed of the west branch of the Battenkill, the limestone appears generally very silicious, having beds of quartz in it. There is also, in the vicinity, and underlying these beds, the black argillo-micaceous limestone described under the sixth variety, and occurring in East and North Dorset. It is generally about horizontal with numerous little convolutions in the strata. North of Manchester depot there is a coarse thick-bedded limestone or dolomite, whose position is indeterminable on account of the abrasion of the strata. Generally between Manchester and East Dorset the limestone is uncommonly well developed, usually dipping about ten degrees northerly beneath Dorset Mountain. In the south part of Dorset, near the line, are several marble quarries, in one of which there is an interesting fold, figured in the Economical Report. In the north part of Dorset, Neoney hill is a small elevation of about two hundred and fifty feet of rather silicious limestone. The valley between Dorset and Danby is extremely narrow, with steep sides. A hill in addition to Neoney hill runs through the valley, composed of limestone.

In passing from Dorset to Sandgate the limestone is continuous over the high mountain into Sandgate. We have not visited the top of Equinox Mountain, but suppose it to be capped with schist like Mt. Eolus. Limestone is certainly found within a thousand feet of the summit. We suppose the limestone passes around the west side of Equinox Mountain, till it unites with the limestone upon the Battenkill River. Thus the schists of Equinox Mountain are left an outlier—an island of schist in an ocean of limestone.

There are excellent marble quarries in Dorset and Danby, high up upon the great mountain. The marble grows thinner, in proceeding north from Dorset. For some distance the beds can be traced by their colors. In Danby there are a few small slides or faults; one of twenty feet, upon the northwest side, and another of six or seven feet in Blake and Barney's quarry. In Griffith's quarry, which was not worked in 1857, upon the southern wall, ten rods long and thirty feet high, the strata make two beautiful curves or undulations. Large stalactitic masses have accumulated in these quarries by the dripping of the water, impregnated with carbonate of lime, often curiously vesicular upon the surface. Interesting trap dikes are in the vicinity, which have altered the colors of the marble locally. Specimens in the Cabinet show the union of the trap and limestone. Sketches of the dikes are given in the account of the unstratified rocks. In the western quarry (Kelly's), there are surfaces which have been smoothed by friction—either from the dikes, or the upheaval of portions of the marble. These layers of marble continue to thin out in a northwesterly direction. But they may be traced around the north end of Danby Mountain, and they probably underlie the whole of this great pile of mountains, and extend north from Danby in two different valleys; the one along the valley of Otter Creek through Wallingford and Clarendon; the other along the eastern base of the Taconic range of mountains, from Danby, through Tinmouth, and the west part of Clarendon. These two lines of marble undoubtedly are parts of the same great sheet, which has been broken by upheaving agencies. There has been very obviously a fracture between the rocks upon Danby Mountain, and those north of a small stream in Danby, flowing eastwards: and the former strata have been greatly elevated. No one can resist the evidence of this fracture, which is so clearly set forth in a nut shell upon Plate VIII, Fig. 2, that we forbear to dwell upon it here.

In the bed of the brook from Danby Pond, near Danby Borough, the limestone appears impure, but rather thick-bedded. It extends uninterruptedly along the valley of Otter Creek, into Wallingford, and probably the marble is continuous the whole distance also.

The limestone from West Dorset is continuous, through a notch on the west end of Mount Eolus, with the limestone and marble in the central part of Danby, upon the west range of the limestone formation. Thus the great pile of mountains in Dorset and Danby is entirely surrounded and underlaid by limestone, and the three different ranges are proved to be integral parts of the one great sheet. The limestone at Danby corners is grayish black, thick-bedded and rather silicious, but containing encrinites. West of Danby Pond there is marble dipping ten degrees easterly. Quartz and limestone are curiously associated together in the north part of the town in connection with some small undulations of the strata. The marble continues north through Tinmouth, Clarendon, Rutland etc., forming the principal source of the marble of Vermont. This range may possibly be connected with the other in Otter Creek valley, by a deep seated synclinal axis. The Tinmouth and Wallingford limestones are described upon Section V. In the east part of Clarendon, the Eolian limestone has the general character of the formation. The dip in the south part is westerly, but in the north part the quartz rock runs under it at a very small angle of inclination. An exceedingly narrow strip of limestone runs up to Rutland, connecting the limestone of the west range in Clarendon with that between the west range of quartz and of slate in Rutland. In the west and southwest part of Clarendon, there are two old marble quarries belonging to A. H. Colvin. The marble there overlies impure limestones and calciferous sandstones. The latter rock continues to Clarendon Springs, often very much resembling some of the lower Silurian group. At Chippen Hook, limestone of good quality is abundant. About the springs the rocks are variable and interesting. Fifty rods south at a mill dam, there is a curious curve in the strata, forming a sharp anticlinal. The strike varies greatly about the springs, being sometimes east and west, but generally N. 10° E.

Most of the limestone here, but not the marble, is a dark gray variety with a coarse texture. Hitchcock's marble quarry is the most northern point where the marble appears. Some disturbance has thrown the rocks into great confusion near the town line of Clarendon and Rutland, as seen by these circumstances. The marble dips west through Tinmouth and Clarendon, to this point, where it disappears. The rocks about Clarendon Springs, and in the northwest part of the town, show unusual marks of disturbance. Where the Rutland road crosses Furnace Brook, talcose schist dips about 50° E., upon the west bank, and encrinal (?) limestone upon the east bank dips 42° W., both at the same level. The schists are found all the way from the bridge to West Rutland, east of the southern prolongation of the Rutland marble. It is most rational to suppose that the two marble ranges must have been connected together formerly; but now they are separated from each other by a mile width of schists, the Clarendon marble dipping 45° W., and the Rutland marble dipping 40° E. The exact nature of this disturbance is not yet ascertained.

The marble continues north through the west part of Rutland, where an immense number of quarries are worked, and terminates a few rods north of Pittsford south line. There is another fault in the strata of marble at West Rutland. See Plate VIII, Fig. 2. The more easterly range east of the marble, but west of Rutland Center, increases greatly in width as it advances north. At Sutherland's Falls there is a marble quarry worked in it. East of the west range of quartz rock the limestone is very thick-bedded and obscure, being probably dolomitic. It is seen in several places upon the Pittsford road. In the north part of Rutland there is a peculiar brecciated limestone made up of the fragments of dark colored limestone and geodic nodules of calcite and quartz, resembling the Plymouth marble. In Pittsford the limestone is generally rough, impure, perhaps magnesian. Valuable beds of marble have been discovered in the northwest part of the town. The ranges of limestone are the most interesting feature of the formation in Pittsford and vicinity.

There are different spurs of limestone in this town east of Otter Creek. The first is in the valley of East Creek, in the extreme southeast part of the town, projecting from Rutland. The next spur runs up into Chittenden, along the valley of Furnace River. Most of it has an easterly dip, but at its junction with quartz rock, at the foot of Bald Mountain, it dips to the west, overlying the quartz rock. Just above the Furnace at Grangerville, the river passes through a very narrow and deep gorge in the limestone. The amount of terrace materials is so great in Chittenden, that the limestone shows itself only three or four times. The most northern ledge we examined was about two miles north of North Chittenden, where erosion has removed all the rock except a single tower thirty feet high. It was difficult to ascertain the position of the strata of the tower. They seemed to run N. 20°E., and to stand upon their edges. A few planes dipping 15° S.W., may possibly have been the lines dividing the layers.

The third and fourth spurs start from Grangerville together, and after a separation of two miles, unite and pass on through Brandon to an unknown termination. Chittenden cave is located upon this spur. The prevailing dip is small to the eastward.

The fifth spur runs up the valley of Sugar Hollow River, from Pittsford village to Lake Dunmore, and perhaps further. Near the north line of Pittsford, the limestone is divided into two beds, by strata of schist and conglomerate. The general character of the limestone in all these spurs is the same. It is a fetid thick-bedded magnesian limestone, weathering black except at Chittenden cave. See Plate II. and VIII, for maps of this interesting region.

The main body of the Eolian limestone from which these spurs diverge, is usually wide in Pittsford. Owing to the soft character of the limestone, much of it has been worn away, leaving a great basin. In fact the limestone is rarely found upon a hill, unless it is protected by an overlying rock of a firmer texture. The sudden termination of the deep valley of Otter Creek, at Sutherland's Falls, may indicate the action of disturbing forces.

Pittsford is unusually interesting for its geological features. One may study here to his profit, the alternation of these different rocks, the tertiary deposits, the alluvial deposits, and interesting cases of old river beds; and as the geologist tarries in the community, he will be charmed by the enterprise and intelligence of the inhabitants.

From Pittsford to Brandon, the rock is mostly concealed by drift, but enough is seen to show that the ledges near Brandon are less highly inclined than those in Pittsford.

The limestones, marbles and dolomites of Brandon are full of interest, as is shown elsewhere. In Leicester the limestone is unusually impure, containing both silex and magnesia. The strata are highly inclined to the east at the eastern border of the deposit or along the west part of Lake Dunmore. Near Whiting Railroad station, there is a small ridge of limestone and marble, extending into Leicester. Generally, in Whiting, east of the slate, the limestone is slaty, obscure, and is but slightly inclined to the east. In Salisbury the limestone is like that described in Leicester. Half a mile south of the village there is a belt of impure talcose schist. In Middlebury, marble is found over an unusually wide area — in the line of strike with that at Whiting station. This is due to the fact that the limestone is quite variable in its position, in consequence of the general small inclination of its strata. In the northwest part of the town, the limestone is dark-colored and contains obscure fossils. In passing north from the village to Belden's Falls, the pedestrian will pass over many interesting marble quarries and beds of limestone, all thoroughly metamorphic. At a quarry near the falls, the quality of the marble is excellent, but the great number of joints traversing it render it unfit for use. Otter Creek has worn a gorge through the limestone adjacent, thereby displaying its lithological character to good advantage. Other ledges of marble are found in the north and east part of Middlebury. But it is sufficient for our purpose to say that most of the town is underlaid by Eolian limestone.

In New Haven and Bristol this rock is divided in the middle by a range of sandstones and shales, joining the red sandrock in Monkton. See Fig. 263, which gives a section through these two towns. East of C. Wright's house, and west of the Rutland and Burlington Railroad, there is limestone of good quality. In Weybridge it is more or less developed. Clay slate is abundant in it in the south part of the town; and as it is north of similar ledges in Cornwall, it may belong to the same range with them.

There is an arm of Eolian limestone running down to Benson, and perhaps to Fairhaven, west of the Georgia slate, from Weybridge. In the southwest part of Weybridge the rock is a gray, silicious, thick-bedded limestone, resembling the upper limestone of the Hudson River group at Snake Mountain. There is sparry limestone at Cornwall Center, and in the west part of the town. The quarry from which the stone was obtained for the building of Middlebury College is in this town, and obscure fossils are found in it resembling fragments of crinoids. This arm of limestone is the principal source of the fossils which have been of service to us in conjecturing the age of the limestone.

It is sufficient to say respecting the occurrence (except Section VII.) of the limestone in this region, that in the northwest part of Whiting, the east part of Shoreham, the west part of Sudbury, that it has the usual characteristics of the group, and that the peculiar configuration of the deposit may be seen on the map. Passing south in Hubbardton, Benson, Castleton, and Fairhaven, we cross over a great many alternations of limestone and clay slate, so numerous that we thought it unadvisable to specify the peculiar localities and number, deeming the general statement sufficient. In Fairhaven this limestone is sometimes sparry—otherwise it is of a bluish or grayish, compact, thick-bedded mass of limestone.

From Bristol, as we return to the point we once reached in our northern course, a valley runs north between Hog Back Mountain on the east, and the hills of Monkton on the west, along a branch of Lewis Creek. Though very narrow in some places, it is barely possible that the limestone may extend along this valley and connect the two deposits of Eolian limestone. Near the north line of Addison County the limestone of the northern deposit appears in several large ledges of a rather ferruginous impure limestone, probably magnesian. As such it is found for two or three miles upon the east side of the semi-vitreous quartz rock into Starksboro; and there is another belt of limestone in the quartz rock in Starksboro and Bristol, parallel to the west border of the quartz rock. Part of its course is along the north branch of the New Haven River, in Bristol.

In Hinesburgh an impure limestone may be traced from the south line through the town beyond the route of Section X. At the village it leaves its north course and turns northwesterly, at the same time expanding greatly, so that in Shelburne it is as wide as in the south part of New Haven. Probably one or two strips of limestone run across the sandstone group through Monkton, and connect the northern and southern Eolian deposits. From the position of these rocks upon the map, one would infer that the red sandstone covers the limestone, as its height is greater, and especially as at Baptist Corner in Charlotte, there is such an abundance of a white tolerably pure limestone, passing beneath the sandstone unconformably. It would not surprise us to learn that the two Eolian deposits were connected by a band of limestone brought up from below the red rock upon one of the folds. Compare with Fig. 263.

In the northwest part of Hinesburgh, the northeast part of Charlotte, and in Shelburne, the character of the limestone has greatly improved. In Shelburne it is worked for marble, and really some specimens from these quarries are as fine statuary marble as can be found elsewhere in the State. But the jointed structure begins very soon to destroy it for marble; yet its purity remains the same, as the lime manufactured therefrom indicates.

Concerning this rock in Chittenden County, Prof. Thompson has written the following: "The most extensive bed of good limestone for quicklime [the continuation of the Shelburne marble] commences a little north from the east meeting house in Colchester and extends south half a mile south of Winooski turnpike in Burlington, and at Winooski River is about half a mile wide. At the quarry opened at the limekilns of Hon. U. H. Penniman, near the high bridge, it is thought that this limestone will make a very good dove-colored marble. In the same range there is a bed of very pure white limestone or marble in the northeastern part of Shelburne, lying to the westward of the pond, and others in the western part of Hinesburgh which will make very good lime.

"This formation consists of compact silicious limestone, a dark greenish shale, a gray finely stratified limestone, a silicious limestone with imbedded fragments and clay slate. The rocks along the eastern border have an average easterly dip of about thirty degrees.

"I have spent much time in searching along the line of the junction of this rock with the slates east, hoping to find them exposed in contact, that I might have ocular evidence of their manner of meeting or overlapping, but my search has been in vain. I found the line everywhere covered and concealed by earth, but in many places the rocks were exposed on the opposite sides of a deep ravine at no great distance apart. A case of this kind occurs in the west part of St. George, where on the west side of a deep narrow valley along which the road passes, the silicious limestone is exposed, and upon the opposite side the magnesian [talcose] slate where its uplift forms a considerable precipice, and the valley is only a few rods wide; but the rocks are there concealed."

We have found an excellent example of the junction of these two rocks at Hubbell's Falls, in the bed of Winooski River. The limestone is tough, thick-bedded, and nearly destitute of seams of stratification. Yet they are sufficiently distinct to show that their inclination is small, a few rods west of the junction; but they stand perpendicular at the junction itself, side by side with the slate. As both the slate and limestone a few rods distant from the immediate junction, have their normal small inclination, we have supposed that a disturbance of a peculiar character was indicated, viz., that the whole body of one of the rocks has been elevated above its normal position. At the same locality there are broken dikes, within fifty feet, showing that a local disturbing cause has also been at work.

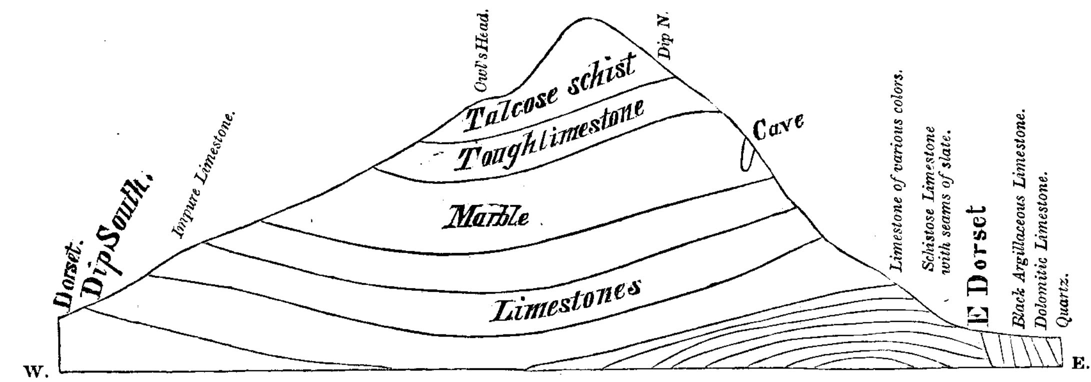
This is the only case of actual union of the two rocks we have seen, but we have seen them within a few rods of each other in several places, as at Colchester depot. These relations are the same everywhere. The dip of the limestone in Colchester is generally very small.

Along the line of the Vermont and Canada railroad between Colchester depot and

Milton Falls, limestone and slate are both found. At the summit level there is slate; near a railroad crossing the limestone is nearly horizontal; north of this as far as the Falls, every ledge is limestone, and that generally of a soft slate-colored variety, like the fossiliferous limestone further south. Beds of limestone are in the quartz rock at Milton Falls, and the formation terminates in a point near the north line of Milton.

The thickness of the Eolian limestone is nearly 2000 feet. The best place to determine it is in the east part of Dorset, upon Mt. Eolus. The strata of limestone are nearly horizontal, composing the greater part of the mountain, and are capped by talcose schist. The base is not reached, but it is certain that the measurement does not embrace any part of the rock the second time. Fig. 264 gives a section of this mountain. The barometer showed 1970 feet difference of elevation between East Dorset and the top of the limestone. There is no doubt that many feet of thickness of layers out of sight at the mountain should be added to make the whole thickness sufficiently great. We have not carefully compared this thickness in Dorset with what might be deduced from other sections, but express the opinion that the limestone is rather greater in amount here than elsewhere. Hence the

Fig 264.



Section through Mt. Eolus.

appropriateness of applying the name, Eolian *limestone*, to this formation, especially in preference to the term *Stockbridge*, for only a part of the formation is developed in that town, and that in an inferior condition to this. The thickness of the same range in New Jersey, as given by Prof. H. D. Rogers, agrees essentially with this, and generally in Vermont the thickness would not fall short of this 500 feet. But it does seem rather strange that there should be such an immense pile of nearly pure carbonate of lime in the same mountain mass.

The numbers in the following enumeration of the thickness of the different beds of limestone upon Mt. Eolus, refer to the specimens collected from them upon the mountain and deposited in the State Cabinet. The specimens illustrate Fig. 264. In ascending from East Dorset to the cap of schist, we pass the following beds:

Schistose limestone, with slaty seams, 106 feet; $\frac{4}{135}$ to $\frac{4}{137}$.
Blue limestone, 47 feet; No. $\frac{4}{138}$.
Silicious limestone, 25 feet; No. $\frac{4}{139}$.
Bluish gray limestone, 110 feet; No. $\frac{4}{140}$.
Limestone with ferruginous seams, 23 feet.

Limestone with slaty seams, 39 feet.
White limestone, 6 feet.
Limestone of the last three varieties probably, obscured by drift along the line of the section, 437 feet.
White limestone, 292 feet.
Bluish limestone, 98 feet.
Silicious limestone, 90 feet.
Marble, with occasional beds of limestone unfit for marble, 479 feet; Nos. $\frac{4}{141}$, $\frac{4}{142}$.
Saccharoid limestone, 142 feet; Nos. $\frac{4}{144}$ and $\frac{4}{145}$.
Blue compact silicious limestone, 86 feet; No. $\frac{4}{146}$.
Talcose schist, capping the limestone, 498 feet; Nos. $\frac{4}{147}$ to $\frac{4}{150}$.

Making a total of 2468 feet, or 1970 feet of limestone and marble. Upon the west side of the mountain the limestone is mostly covered by drift; but what is seen corresponds with that upon the east side.

Mineral Contents.

Of course the purer varieties of this formation, the marbles, constitute a mineral by themselves, and might strictly be enumerated among them. Of this there is an exhaustless store in Vermont. The same is true of amorphous dolomite.

The mineral calcite, or crystallized carbonate of lime, is found abundantly in the geodic and other cavities of this rock. It is best seen at Hubbell's marble quarry on the north side of Mt. Anthony, in Bennington. A vast amount of flesh-colored and red calcites are found there sufficiently perfect to illustrate the species well in a Cabinet. (See No. $\frac{2}{99}$, and 328 to 331 of the minerals in the State Cabinet.) We noticed it particularly, also, in the towns of Middlebury, Orwell, Burlington and Colchester.

Calcareous tufa is found in Middlebury, etc. Stalactites and stalagmites are found in Dorset, Danby, Middlebury, Weybridge, etc. Agaric mineral is rare, though found occasionally.

The limestone in Chittenden County frequently contains very fine limpid hexagonal crystals of quartz disposed in the small cavities which frequently occur in it. In Dorset the crystals of quartz are very good (See Nos. 134 to 137, and 141 to 143.)

In Middlebury milky quartz is found, not in crystals.

In Weybridge, earthy asbestus is found near Pepu Hill. The hornblende minerals are not found in the limestone of Vermont, but are very finely developed in the same range in Massachusetts—as the minerals tremolite, white augite and sphene.

In Middlebury, there is black mica and iron pyrites in the limestone. Also epidote on Chipman's Hill. A few specimens of limestone are coated with a film of green talc. Elegant crystals of titanium, from one five-hundredth to one one-hundredth of an inch in diameter and mostly an inch long, are very abundantly disseminated in a fragment of a transparent smoky quartz crystal from Bristol.

Albite is said to occur in the Eolian limestone in Castleton.

Bowlders containing the crystalline and metamorphic minerals are sometimes found extensively upon this formation. In Middlebury in this way there are zircon, galena, copper pyrites, jasper, tourmalin, serpentine, hypersthene and hornblende. In Weybridge, hypersthene and Labradorite are found, similarly transported.

The minerals in the trap, etc., dikes in all these sedimentary rocks, are mentioned under igneous rocks; one of the most interesting is a dike of lithomarge in North Dorset.

Organic Remains of the Eolian Limestone.

Although the Eolian limestone is largely distributed in our country, no fossils have been found in it, except the few which occur in Vermont. We have found the following genera, to which specific names cannot yet be attached: *Euomphalus, Zaphrentis, Stromatopora, Chætetes* and *Stictopora*. Two kinds of encrinal plates have also been discovered. These genera were determined by Prof. James Hall.

Euomphalus. This is a genus of univalve mollusk, somewhat resembling Maclurea and Ophileta. It is most common in the Devonian and carboniferous rocks, though not wanting in the lower Silurian. This genus has been collected from the Eolian limestone in Whiting and Sudbury. A shell of the same genus is found in the Hudson River limestones in Orwell, which is quite near the locality in Sudbury. There are two species of Euomphalus in the Eolian limestone.

Zaphrentis. The three other genera are of corals. *Zaphrentis* belongs to the family of *Cyathophylidæ*, and there is no instance in this country where this genus has been found below the horizon of *Atrypa reticularis*, which is an upper Silurian and Devonian species. The two are found together in great abundance in the semi-crystalline limestone connected with clay slate upon Lake Memphremagog near talcose schist. We cannot ourselves distinguish between the specimens of *Zaphrentis* from Lake Memphremagog and the Eolian limestone.

This genus occurs in a dark colored slaty limestone in Sudbury and Cornwall, associated with Euomphalus and Chætetes.

Stromatopora. This is the most common of all the fossils in the Eolian limestone, and it is a genus whose lower limit is in the Niagara group of upper Silurian rocks. It has been found in Sudbury, Orwell, Cornwall, East Middlebury, Brandon, New Haven and Williston. The specimens from East Middlebury and Williston are referred to this genus with a query. There are probably two species of Stromatopora in the Eolian limestone.

Chætetes. This genus is both an early and late one—that is, it is found from the lower Silurian to the carboniferous rocks. Both branching and oval forms of this genus occur in the Eolian limestone of Vermont, and there are two distinct species of it. It has been found in Sudbury, Benson, on M. C. Rice's farm, Cornwall and Williston.

A supposed fossil of this genus is quite common at Peck's quarry in Cornwall, and on Dea. Casey's farm; at New Haven on the railroad north of New Haven railroad bridge, and in a loose block of limestone at Middlebury village.

In Sudbury were also collected specimens of the genus *Stictopora*. This genus was remarkably well defined. Prof. Hall did not venture to pronounce upon the species.

An obscure coralline form, distinct from any of the others described, has been found in the limeston- above Sheldon & Slason's marble quarry, in West Rutland.

The large encrinal stems from Sudbury and Cornwall are interesting, because the only cases where encrinal rings of such dimensions have been found in this country are in Devonian rocks.

The fragments of small encrinal stems that have been discovered in the Eolian limestone, were found at the marble quarries in East Dorset, upon Mt. Eolus, and in West Rutland, Sudbury and Cornwall.

One will be struck with the fact that all these fossils have an upper Silurian or Devonian character, wherever they are of value in identifying strata.

*Geological Position, Origin, and Equivalency.**

We quite despair of satisfying ourselves or others on these points in respect to the Eolian limestone. The facts are very remarkable, but we doubt whether we have been able to seize upon the fundamental principle that will harmonize and explain the whole. When we throw out our suggestions, let it not be thought that we are very tenacious of them. We have tried to work out the relative position of this formation and its characters, so that our maps and sections will show them. But how the strata came into the positions they now occupy, is a question of great difficulty. Our facts, we trust, will be of service to future explorers; but we cannot hope as much from our hypotheses.

Mount Eolus contains, as already remarked, the most remarkable development of white limestone in New England. As we ascend its eastern face from East Dorset, we shall

*By E. Hitchcock, Senior.

find a succession of strata to the height of about 1900 feet, with a nearly horizontal position; though upon the whole, dipping a few degrees to the west. This is capped by a few hundred feet of Talcoid schist, which at its easterly edge, has a small, westerly dip, but on the western slope of the mountain, the dip is easterly, as it is in the underlying limestone, and this is the general dip of the rocks all the way to the New York line. If we pass along the south end of Eolus, we shall find the limestone dipping westerly for a time, and reversed in its dip towards the west side. The marble shows itself, also, across the north end of Danby Mountain, which is a northern continuation of Eolus. Along the top of these mountains, a gentle synclinal axis shows itself, both in the schist and the limestone, as may be seen by the arrows on Plate VIII, Fig. 2, which represents the position of these rocks from Eolus to Rutland. Still further west it will be seen that an anticlinal extends from Danby Mountain to Rutland, though in all that region the prevailing dip is easterly. But in the whole region occupied by the Eolian limestone there is great irregularity of dip, as our table of strikes and dips will show. On this point we shall make further remarks in the sequel.

To the north of Eolus the limestone descends on the line of strike, and shows itself entirely beneath the talcoid schist nowhere north, we believe, of Danby mountain, across whose north end we have traced it. But southwesterly from Eolus we find it on Equinox Mountain in Manchester, as high perhaps as on Eolus. We have not, however, explored the west side of that mountain, and cannot say whether it crops out there. But proceeding southerly to Arlington, and passing westerly down the Battenkill, between high mountains of talcoid schist we find limestone with a very small dip, generally east, but sometimes west, underlying the strata most of the way for several miles, and at the east base of the mountains it yields abundance of white marble. Passing south to Bennington we find that the limestone shows itself at a high line on Mount Anthony, with a small westerly dip with a cap of talcoid schist. This same schist also passes under it, as it does all along this range of limestone from Rutland to Bennington; and if we go southerly to Saddle Mountain, in Adams, Massachusetts, we find the same relative position of the two rocks, although the limestone there appears in less force than in some of the Vermont mountains.

Here, then, we find a deposit of crystalline limestone, extending over fifty miles on its line of strike, and with a maximum thickness of 1900 feet, underlaid and overlaid by talcoid schists of very great thickness. Moreover, the greater part of the beds affect a horizontal position, a fact perfectly anomalous in the crystalline limestones of New England.

The first question of importance is, how came these rocks into their present position? Were the present precipitous and lofty ridges thrust up by some internal force, or were the valleys between them once filled by similar rock, which has been since removed by erosion? The latter supposition is made probable, nay is almost demonstrated, by the facts detailed by us, when treating of erosion, respecting the cave on Eolus, and the old river bed, high on the side of the mountain in Pittsford, as well as by other facts detailed under that subject. It may be that these rocks not only once filled the valleys, but extended over the Green Mountains, as we have proved other rocks to have done, that have now nearly disappeared. In that case the limestone and schists were probably crowded into successive folds, the remnants of which we still find in the anticlinal and synclinal axes not uncommon. As we go west the strata show less of plication. The horizontal position of the strata on Eolus, Equinox, &c., may be the top or bottom of the folded axes; though we can easily believe that the enormous lateral pressure which seems to have been exerted along the west side of the Green Mountains, may have lifted up the strata bodily, to a great height.

But where among the palæozoic rocks shall we find such a thickness of limestone, and of slate, capable of becoming talcoid, as occur in these mountains? Nowhere unless it be in the lower Silurian, or the carboniferous groups. The Professors Rogers make their Auroral magnesian limestone (the equivalent of the Chazy limestone of New York) 2500 feet thick in Pennsylvania, and the Matinal argillaceous limestone immediately above the Auroral, 550 feet, succeeded by black slate and shale some 1600 feet thick, which might by metamorphosis be converted into talcoid schist. But there are great difficulties in making these rocks as old as the lower Silurian. 1. We have already shown that along the west margin of the fossiliferous rocks, say at Whitehall, we find the older Silurian rocks lying upon the gneiss in undisturbed position, and succeeding one another regularly, as we go east, as high certainly as the Hudson River group. Most of the talcoid schists and the Eolian limestone lie apparently above all these, and though they have been a good deal disturbed, yet how to bring them into the lower part of the lower Silurian we know not, without supposing the most improbable vertical movements along the lines of undiscovered faults, and total inversions of the strata. 2. A still stronger difficulty lies in the facts we have discovered, in respect to organic remains. As detailed above, we have found, mostly in strata below the middle of the limestone, fossils, which, though obscure from metamorphism, are clearly referable to genera characteristic of Devonian rocks, viz., the Euomphalus, Stromatopora, Zaphrentis, Chætetes, and encrinal stems. The limestone in which they occur, exceedingly resembles that from Memphremagog, which contains other fossils of a decidedly upper Silurian or Devonian type.

But neither in the upper Silurian nor the Devonian, as they have been explored in other States, do we find limestones of sufficient thickness to have produced the Eolian. But in the carboniferous rocks, above the Devonian, the Umbral series of the Professors Rogers, we find a thickness of 300 feet assigned to red shales and limestone. Nor is there any improbability, as we shall shortly show, in supposing that Eolian limestone may be as recent as the carboniferous rocks. We incline to the opinion that they must probably be placed as high as that formation, or as low as the lower Silurian: to which last position Mr. S. T. Hunt assigns them. Either supposition abounds with difficulties, and we are hardly prepared to choose between them. We have already stated the views of Prof. Emmons as to this limestone. The fossils seem to be the greatest objection to them.

The metamorphism is generally accomplished in the wet way, that is, water is the principal agent. Where the metamorphism has been most thorough, we have reason to suppose the water to have been hot, and that the whole has been brought into a plastic state, so as to allow of the introduction and abstraction of foreign ingredients. A striking evidence of this plastic condition is seen in the Winooski marble, which is a silicious dolomite, according to the analysis of C. H. H. in his Report. When polished we perceive that the harder parts were broken up into angular fragments, mostly of the red parts, which look as if they were disseminated through a tenacious paste. The white or crystalline parts of the stone have taken the form of very irregular jagged veins in which the red angular fragments, sometimes nearly dissolved, seem to float as the fragments of ice in a river in a winter's flood. The brecciated dolomitic (Hunt) marble of Plymouth, with a dark base, contains a vast number of elongated fragments of compact limestone, though it does not so clearly prove a plastic condition as the Winooski marble. We regret exceedingly not being able to give a sketch at least of this latter rock. But we have not pecuniary means for even one wood cut more. We hope, however, that the citizens of Vermont will patronize the Winooski marble enough to obtain at least a table top, and they will then have before them (though this is true of only one variety) a much better exhibition of these interesting phenomena than a photograph could give.

The simplest form in which limestone begins its course, is that of marl found in the bottom of ponds deposited from the water, and of which beds are marked upon the Map of Surface Geology. They consist, as fully explained elsewhere, of carbonate of lime in the form of powder, with clay and numerous little shells. This at length may be consolidated by the same substance held in solution, and thus it becomes a soft rock. The water may hold in solution, also, iron and silica, and perhaps carbonate of magnesia, and these also become solid; and we have compact silicious limestone, perhaps with magnesia; or this last ingredient may be in so large quantity that the rock becomes dolomitic, that is, it has more than 40 per cent. of carbonate of magnesia in it. Thus far the rock does not show much of crystallization, though often traversed by veins of calcareous spar, filled by the deposition from water. It is also more or less colored, and may have a dirty aspect. But up to this point no great degree of heat is necessary. Suppose now by the upward permeation of heat, hot alkaline water penetrates the rock. "The organic substance (by which the color is produced) is gradually removed by water, while carbonate of lime is deposited in its place. If this displacement was complete, white granular limestone would be produced: when not complete, gray limestone would be produced. In this manner the origin of the gray streaks, veins and spots, is quite intelligible. In the conversion of sedimentary limestone into granular limestone the fossils are generally quite obliterated" (Bischof.)

The enormous development of white limestone in the Eolian formation, is a magnificent example of the metamorphosis above described. On Mt. Eolus and Danby Mountains alone, to say nothing of Rutland, one would think there is marble enough to supply the whole country till the Millennium; and if more should be wanted during that period, we think Equinox, Anthony and other mountains to the south would supply the demand.—The counterpart to this formation in Europe is the Carrara marble. Whether the beds are as thick as in Vermont we know not; but the quarries have been wrought since the time of Julius Cæsar, and 1200 men are now employed in them. The resemblance between the Carrara marble and that from Eolus, has already been referred to, and it is surely close enough to infer that whatever changes the Carrara rock has undergone have passed over the Eolian. Now the following facts in regard to the Italian rock have recently been ascertained, which we give in the language of Bischof:

"The granular limestone of Carrara is described by Hoffman as gradually passing into compact fossiliferous Jurassic limestone, in such a manner that the connection between their origin is unmistakable. He expresses his astonishment at meeting with clay slate, mica slate, talcose slate and gneiss, situated in such positions as regards fossiliferous limestone, as to leave no doubt of their connection, and of the simultaneity of their formation. The slates not only follow immediately and regularly after the limestone, but alternate with it, and pass into it, and blend with it so intimately, that the latter must be regarded as unquestionably one of the sedimentary rocks. He considers it, as well as the slates and gneiss, to have been metamorphosed by igneous action, and ascribes the result to the protrusion of granite. But at the same time, he adds, that in this part of Italy scarcely any granite occurs, although in this place the valleys are deep cut.

"There can be no doubt that the marble of Carrara is a metamorphic rock; however, this metamorphism has been effected not by imaginary granite, but by the action of water. By this alteration the fossil remains have been obliterated," &c.

In regard to granite in the vicinity of the Eolian limestone, we may say decidedly that none occurs within any such distance as can by the most ultra-Plutonian be supposed to have any connection with the metamorphism of the rock. On the west we must go into the mountains of New York, and on the east to Ascutney on the Connecticut River, in order to find granite. Small trap dikes do indeed occur in the limestone, but they affect the rock only a few feet; the metamorphism therefore must have been aqueous.

The origination of the Carrara marble from rocks as new as the Jurassic or Oolitic, does not prove that the Eolian limestone was derived from so recent a rock. But the fact takes away all improbability from the supposition hinted at above, that this limestone may be as new as the carboniferous limestone.

On Ram Island, in Lake Champlain, we find a rock which is called silicious or flinty slate, analogous to flint. We may as well say in this place, how such a rock might be formed from calcareous slate. Says Bischof, "The conversion of calcareous slate into hard porous stone indicates a penetration of silica and the displacement of carbonate of lime by silica, which may be supposed to have taken place, since pseudomorphous quartz with the form of calc-spar, does occur; and it has already been sufficiently shown that this alteration could take place only in the wet way."

So far as our analyses have gone, although a few per cent. of magnesia occurs occasionally in the Eolian limestone, yet it rarely contains enough to form the double carbonate called dolomite. But the white limestones on the east side of the Green Mountains, in the schists and gneiss, are almost all dolomite, as the Chemical Report shows. And this is a general fact we believe in all places. But it has exceptions. Thus the beautiful white limestone of Whitingham, in gneiss has 97 per cent. of carbonate of lime, and only 2 per cent. of carbonate of magnesia.

The mode in which such dolomites have been formed has not been explained exactly alike by all chemical geologists. The fact, however, that the quantity of magnesia is much smaller in less metamorphosed strata than in those where the change has reached its maximum, shows, we think, that the dolomites of the schists and of gneiss have been formed from pure carbonate of lime, which has been in some way produced in the process of metamorphism. The old notions that it has been done by igneous fusion, or by the sublimation of carbonate of magnesia, do not all satisfy the facts as we now understand them. The views of Bischof are given in the following language: "Taking into consideration all the facts known with regard to dolomite, so far as it occurs as a rock mass, it can only be regarded as a product of the alteration of limestone in the wet way; and there is no mode of alteration that is more probable than the substitution of carbonate of magnesia present in water for a portion of the carbonate of lime in limestone, or the extraction of the greater part of the carbonate of lime by the water permeating the limestone."

We are not sure that the views of T. Sterry Hunt, who has discussed this subject with great ability, differ very much from the above, though he seems to regard dolomite in its origin as from sediments, for he brings in "the subsequent action of heat." He says, "Dolomites, magnesites and magnesian marls have had their origin in sediments of magnesian carbonate of magnesia. These solutions have been produced by the action of bicarbonate of lime upon solutions of sulphate of magnesia, in which case gypsum is a subsidiary product; or by the decomposition of solutions of sulphate or chlorid of magnesium by the water of rivers or springs containing bicarbonate of soda. The subsequent action of heat upon such magnesian sediments, either alone or mingled with carbonate of lime, has changed them into magnesite or dolomite."

Limestone, especially such as the Eolian, is remarkable for caverns sometimes of great length. We have already expressed an opinion that the cave on Eolus was once the bed of a stream, and have deduced important inferences from the fact. We have the highest authority for the opinion that all caverns in limestone thus originated. "There cannot," says Bischof, "be any other explanation given of the origin of these caves than that they have been hollowed out by water. The fissuring of the strata must have preceded this action so that the water might penetrate. But the fissuring of rocks is a very general phenomenon. There is, however, this difference between limestone and slate or sandstone strata: that the constituents of the former are soluble in water and are therefore removed, either wholly, or for the most part, while the constituents of the latter are but partially soluble, or decomposable by water. It is for this reason that caves occur with few exceptions only, in limestone rocks."

TALCOID SCHISTS.

SYNONYMS.

Mica Slate and Talco-micaceous Slate (in Berkshire Co., Mass.): *Prof. Chester Dewey's Geological Map of a part of Massachusetts, etc.; American Journal of Science and Art*, I. Series, Vol. VIII, 1824.

Mica Slate (Berkshire Co.): *Geological Report of Massachusetts*, 1832; *by Prof. Edward Hitchcock.*

Talcose Slate and Mica Slate (Berkshire Co.): *Final Geological Map of Mass.* 1842; *by Prof. Edward Hitchcock.*

Magnesian Slate: *Prof. E. Emmons' works on the Taconic System*, 1838–1860.

Hudson River Group: *Geological Map of New York*, 1842.

Magnesian Slate (Provisional): *Annual Report upon the Geology of Vermont*, 1845–1848; *by Prof. C. B. Adams.*

Magnesian Slate: *Appendix to Thompson's Vermont*, 1853; *by Prof. Zadock Thompson.*

Upper Hudson River Group: *Elementary Geology*, 31st edition, p. 411, 1860; *by Edward Hitchcock and C. H. Hitchcock.*

Talcoid Schists: *The present Report.*

This group of rocks has generally been associated with the slates of the Georgia group, having been regarded both as Lower Silurian and sub-Silurian, by different authors. We propose to describe it as a separate group, although it may include rocks of different ages. The rocks thus specified form one great band, though somewhat broken by erosion, extending from the south line of the State as far north as Pittsford.

Lithological Characters of the Group.

1. Talcoid schists are the prevailing rocks of the group, but the following varieties of rock are associated with them:

2. Talco-argillaceous schists,
3. Talco-micaceous schists,
4. Talcoid grits,
5. Talcose conglomerates,
6. Beds of clay slate,
7. Beds of limestone.

The most common rock of the group is what geologists have been in the habit of calling talcose schist, and what Emmons calls magnesian slate, from the supposed presence of magnesia. Much of this schist is of a light gray color, and much of it is of rather a green color. A darker shade is sometimes imparted, by the presence of decomposing sulphurets. It has an unctuous feel, like the genuine magnesian schists. A specimen of the common variety of schist from Pownal has been analyzed, and the following are the proportions of its constituent parts:

Silica,	42.90
Alumina and peroxyd of iron,	42.20
Lime,	.78
Magnesia,	1.98
Potassa,	5.24
Soda,	1.33
Loss by ignition,	5.60
	100.03

This is clearly an aluminous schist. It approaches the mineral *dysyntribite* in its composition, also the mineral *talckite*. The former is found in the Laurentian rocks, in Northern New York, and the latter is found in Cambrian schists in Ireland. Owing to the absence of magnesia in this rock, the name talcose is a misnomer. Accordingly we have adopted the term *talcoid schist* to designate this bed of rocks. The name talcose is not yet gone out of use, and is used for this rock in some parts of this Report. It is difficult to fix upon any satisfactory definite term for this rock, in this transitional period of its history.

We would refer all those interested in the subject to an essay upon the proper name of the talcose schist of Vermont, under the heading of *talcose schist* among the azoic rocks.

This common variety is found upon every section crossing the formation. It has a peculiarly bright color in its westerly portions in Rutland County, also upon a small range of this rock running from Fairhaven to Sudbury.

Perhaps the most common variety of the talcoid schist is what we have denominated talco-argillaceous schist. It is composed of a mixture of the common talcoid and argillaceous materials, sometimes the one, and again the other predominating. Often carbonaceous matter is present; so much so as to blacken the hand by contact with it. In the Cabinet there are specimens of this variety from Pownal, both from the small deposit of this rock interstratified with the Eolian limestone, No. $\frac{1}{88}$, and from the principal range, Nos. $\frac{1}{94}$, $\frac{1}{95}$. It is common upon Mt. Anthony, and in the west part of Bennington and Arlington. Nos. $\frac{4}{147}$, $\frac{4}{148}$, and $\frac{4}{150}$ are of this variety, from the cap rock of Mt. Eolus. No. $\frac{4}{168}$ is from East Rupert. No. $\frac{6}{52}$ from West Rutland, upon a spur of this rock projecting from the main belt, is plumbaginous. This variety does not seem to be confined to any one part of the series.

The third variety, talco-micaceous schist, is more common in this rock in Massachusetts than in Vermont. It seems to be merely a further stage in the history of the rock, as it has experienced a greater degree of metamorphism. This variety may be considered a mixture of the three minerals, quartz, talckite and mica. It may be either a mica schist taking talckite into its composition, or a talcoid schist containing mica. Probably a large part of the talcoid schist contains a small proportion of mica, or its constituents. See No. $\frac{1}{87}$ in the Cabinet, from Pownal.

Occasionally there are talcoid grits associated with these schists. By talcoid grits we mean a rock having the same color as the schists and the same general texture, but it has a harsh feel, and is evidently mostly silicious in its composition. It passes into quartz rock. Rarely this quartz rock is filled with numerous minute crystals of iron pyrites.

These schists are filled in many places with irregular veins of quartz, not only hyaline, but a fetid, porous quartz, from which some substance has been removed by decomposition. The decomposing substances resemble chlorite. These veins are very common, and resemble veins of hyaline quartz in the azoic talcose schists of Vermont, except that the latter are not porous.

There is a peculiar kind of conglomerate associated with the talcoid schists of Rutland County. It consists of transparent quartz pebbles in a talcose paste. It is abundant in Ira, Middletown, Wells, Poultney, and Pawlet. Upon Bird Mountain, in Ira, it constitutes the mass of the rock. The pebbles are generally about the size of kernels of corn. The rock on the summit is curiously mottled, and the conglomerate occurs in spots over its surface. Its decomposition gives rise to a black powder, much like the peroxyd of manganese. See Nos. $\frac{5}{229}$, $\frac{5}{242}$, $\frac{6}{175}$ and $\frac{6}{76}$ in the Cabinet.

This conglomerate reminds us at once of the talcose conglomerates of Northern Vermont, but not so much from its lithological appearance as its association with the so-called talcose schists. We are not sure but that the advocates of the Taconic system would regard the talcoid schists and the talcose conglomerates as belonging to the same belt of rocks, though the continuity was destroyed by the erosion or depression of some parts

of the group below the surface. Professor Adams, in his first report, refers the belt of talcose conglomerates to the Magnesian slates. Professor Emmons speaks of the conglomerate of Bird Mountain as a fine exhibition of the lower beds of the upper division of the Taconic system.

There are narrow beds of clay slate in the west part of the talcoid schists, where they approach the clay slate of the Georgia group. For an illustration, we refer to Section IV, in Rupert. At a Mr. Tobin's house, on the east side of the mountain, there is a band of clay slate two rods wide. Another, a quarter of a mile further west, is an eighth of a mile wide. Perhaps other beds of clay slate might be found between the top of the mountain and the village of Rupert, were not the rocks mostly obscured by drift.

There are several beds of limestone in the talcoid schists, of small extent. In the west part of Bennington there is a bed of saccharoid limestone, containing a few crystals of mica (No. $\frac{2}{107}$.) There is another in the southwest part of Shaftsbury. There is a very thick bed of limestone in the west part of Sandgate. Upon the top of the Taconic range of mountains, in Rupert, there is a bed of dark colored, fetid, compact limestone, three feet wide. A similar rock shows itself through the whole of the east part of Pawlet (Nos. $\frac{4}{194}$, $\frac{4}{196}$.) It is, perhaps, three-fourths of a mile wide. Northwest of Adair's marble quarry in South Wallingford, there are two beds of dark blue limestone. One is three feet, and the other several rods wide. There is also a bed of ferruginous limestone, and two small beds of silicious limestone among the schists in the west part of Wallingford. Another bed is in Wells (No. $\frac{5}{227}$.) Others are in North Middletown and South Ira.

There are three large beds in Ira which are fossiliferous. The most eastern is about three miles southwest from West Rutland, near the east line of the town, upon the land of Joseph Tower. It is a dark blue, compact limestone, breaking into long, angular fragments, and weathers whitish. There is an immense amount of this limestone, for it is at least twenty rods wide, and its northern and southern limits are unknown. A bed of limestone upon Ira Mann's land, west of Tower's bed, is twenty-five feet thick, impure, and gradually changing into the slate above and beneath it. There is another bed of fossiliferous limestone on the south line of Ira, next to Middletown.

There is an immense bed of limestone in the schists, lying partly in Ira, but mostly in West Rutland, imbedded in the talcoid schists. It is very dark blue, nearly black. There is still another, of less size, west of this. Possibly the two large beds in Ira, the one on Ira line, and in North Middletown, are the continuation of the large bed in Pawlet. There are also small beds of limestone in the talcoid schists in Castleton and Hubbardton, but they do not deserve further notice.

This group of talcoid schists differs further from the talcose schists of the azoic rocks, in the fact that there are no beds of steatite and serpentine found in it. If these rocks originate from the alteration of beds of dolomite, as seems probable, then this distinction may not be valid, because the dolomitic beds of these talcoid schists would have been changed, had the circumstances demanded. Furthermore, there are beds of agalmatolite in the slates of this age in the south, which may correspond to the steatite of the northern talcose schists. Who knows but that an analysis of the so-called steatites of the talcose schists would resolve them into agalmatolite, which is a silicate of alumina, while the steatite is a silicate of magnesia? If there is no magnesia in the schists, why should there be any in the inclosed beds of steatite? We have seen specimens of what the discoverer, Rev. E. H. Newton, of Salem, N. Y., has called granular talc, taken from the talcoid schists in the west part of Arlington, which may correspond to the beds of agalmatolite in the south. We understand there is quite a thick deposit of this granular talc in Arlington. The only specimen of it we have seen is in the Newton Cabinet, in the Theological Seminary at Andover, Massachusetts.

STRIKE AND DIP OF THE STRATA.

THE TALCOID SCHISTS.

Locality.	*Strike.*	*Dip.*	*Observer.*
Pownal, south part,	N. 45° W.,	45° N.E.,	C. B. A.
Pownal, middle,	N. 25° E.,	25° E.,	E. H. and A. D. H.
Pownal, middle,	N. 25° E.,	15° E.,	A. D. H.
Bennington, Mount Anthony,		12° S.E.,	C. H. H.
Bennington, Whipstock Hill,	N. 33° E.,	30° E., and rarely 10° E.,	C. H. H.
North Bennington,	N. 10° E.,	Dip east,	A. D. H. and C. H. H.
Waloomsac, N. Y.,	N. 10° E.,	60° E.,	C. H. H. and A. D. H.
Shaftsbury, Cranston's quarry	N. and S.,	10° E.,	A. D. H.
West Arlington, State line,	Av. 10° W.,	60° E. and 60° W., also,	C. H. H.
West Arlington,		25° E.,	C. H. H.
Dorset, top of mountain,	N.E. and S.W.,	12° N.W.,	E. H. and C. H. H.
Dorset, near top,	East of north,	7°–8° W.,	E. H. and C. H. H.
Rupert, east line,	N. 40° E.,	12° S.E.,	C. H. H. and E. H., jr.
Rupert, east part,	N. 45° E.,	30° S.E.,	C. H. H. and E. H., jr.
Rupert, east part,	N. 20° E.,	37° E.,	C. H. H. and E. H., jr.
Rupert, east of village,	N. 5° E.,	30° E.,	C. H. H. and E. H., jr.
Danby, near Danby Borough,	N. 10° E.,	17° E.,	A. D. H. and E. H., jr.
Danby Corners,	N. 15° E.,	20° E.,	A. D. H. and E. H., jr.
Danby Corners, east of,	N. 20° E.,	Av. 25° E.,	C. H. H.
Danby, north part,		Dip east,	C. H. H.
Danby, west part,	N. 15° E.,		A. D. H.
Danby, northwest corner,	N. 30° E.,	28° E.,	A. D. H. and E. H., jr.
Wells, southeast part,	N. 20° E.,	Dip east,	A. D. H.
Wells, south part,	N. 20° E.,	30° E.,	E. H., jr. and A. D. H.
Middletown, west part,	N. 10° E.,	32° E.,	A. D. H.
Middletown, northwest part,	N. 35° W.,	20° N.E.,	A. D. H.
Middletown, west of center,	Av. N. 10° W., irregular,	10° E.,	A. D. H.
Middletown, northeast of center	N. 10° E., irregular,	5° E.,	A. D. H.
Middletown, east part,	N. 10° E.,		A. D. H.
Middletown, northeast part,	N. 15° E.,	25° W.,	A. D. H.
Middletown, north part,	N. 10° E.,	10° E.,	A. D. H.
Tinmouth, west part,	N. 20° E.,		A. D. H.
Tinmouth, north part,	N. 25° E.,	18° W.,	A. D. H.
Tinmouth, southeast part,	N. 20° E.,	65° E.,	C. H. H.
Tinmouth, west part,		15° E.,	A. D. H.
Tinmouth, west part, in a gorge,	N. 20° E.,	27° E.,	C. H. H.
Wallingford, southwest part,	N. 20° E.,	44° E.,	C. H. H.
Wallingford, southwest part,	N. 20° E.,	55° E.,	A. D. H.
Wallingford, southwest part,	N. 20° E.,	75° E.,	C. H. H.
Wallingford, southwest part,		55° W.,	A. D. H.
Wallingford, southwest part,	N. 20° E.,	42° W.,	A. D. H.
Clarendon, north part,	N. and S.,	12° E.,	A. D. H.
Clarendon, north part,	N. and S.,	10° E.,	C. H. H.
Clarendon, southwest part,	N. 30° E.,	10° W.,	A. D. H.
Clarendon, west part,	N. 40° W.,	10° E.,	A. D. H.
Clarendon, west part,	N. 30° E.,	10° W.,	A. D. H.
Clarendon, west of Colvin's marble quarry,	N. 50° W.,	34° N.E.,	C. H. H.
Clarendon, west line,	N. 30° E.,	Dip west,	A. D. H.
Clarendon, north line,	N. 30° E.,	50° E., and rarely 90°,	C. H. H.
Ira, north part,	N. and S.,	40° E.,	C. B. A.
Ira, north part,	N. 15° E.,	45° S.E.,	E. H., jr.
Ira, Bird Mountain,	N. 30° E.,	5°–8° W.,	C. H. H.
Ira, south of Bird Mountain,	N. 20° E.,	45° E.–50° E.,	A. D. H.
Ira, east of Bird Mountain,	N. 20° E.,	25° E.,	C. H. H.
Ira, east part,	N. 25° E.,	25° E.,	A. D. H.
Ira, east part,	N. 25° E.,	40° E.,	A. D. H.
Ira, southerly part,	N. 20° E.,	22° E.,	A. D. H.
Ira, southerly part,	N. 20° E.,	20° E.,	A. D. H.
Ira, west part,	N. 20° E.,	22° E.,	A. D. H.
Ira, Herrick Mountain,	N. 15° E.,	25°–60° E.,	A. D. H.
Ira, east base of Herrick Mountain,	N. 20° E.,	40° E.,	C. H. H.
Ira, southwest part,	N. 15° E.,	22° and 20° E.,	A. D. H.
Ira, west part of the gorge,		35° E.,	C. H. H. and E. H., jr.
Ira, east part of the gorge,		20° E.,	C. H. H. and E. H., jr.
Castleton, east of center,	N. and S.,		A. D. H.
Castleton, southeast part,	N. 20° E.,	50° E.,	A. D. H.
Castleton, southeast part,	N. 20° E.,		A. D. H.
Fairhaven, west part,	N. 40° W.,	55° N.E.,	E. H., jr. and A. D. H.
Fairhaven, west part,	N. 30° E.,	42° E.,	E. H., jr. and A. D. H.
Rutland, southwest corner,	N. and S.,	15° E.,	A. D. H.
Rutland, southwest part,	N. and S.,	20° E.,	A. D. H.
Rutland, west part,	N. and S.,	17° E.,	C. H. H.
Rutland, west part,	N. 10° W.,	25°–40° E.,	A. D. H.
West Rutland, east range of schist,	N. 30° E.,	30° E.,	C. H. H.
West Rutland, east of the quarries,		35° E.,	A. D. H.
Rutland, northwest part,		Frequently horizontal,	A. D. H.
West Rutland, east of quarries,	N. 30° E.,	40° E.,	C. H. H.
Pittsford, southwest part,	N. and S.,	60° E.,	A. D. H.
Pittsford, southwest part,	N. and S.,	40° E.,	A. D. H.
Pittsford, southwest part,	N. 10° W.,	30° E.,	A. D. H.
Pittsford, west part,	N. and S.,	30° E.,	A. D. H.
Pittsford, west part,	N. and S.,	40° E.,	A. D. H.
Pittsford, east of do.,	N. and S.,	30° E.,	A. D. H.
Pittsford, northwest part,	N. and S.,	65° E.,	C. B. A.

Two features of the stratigraphical position of the talcoid schists are presented by this table. First, the great body of the formation dips to the east. All of the formation south of Mount Anthony, and all that lies west of a line running from the west base of Mount Eolus, the west base of Equinox Mountain, to the foot of Mount Anthony, also dips eastwardly. The small ranges in Rutland County, as well as the spur in West Rutland, also dip eastwardly.

Secondly, the talcoid schists resting upon the thick Eolian limestones of Mount Eolus, Equinox Mountain, Bald Peak, Spruce Peak, Mount Anthony, and all the range connecting these summits, have a westerly dip. Supposing that these rocks exhibit their original relations to one another, we should have the greater part of the talcoid schists dipping beneath the Eolian limestones, while a smaller portion overlies the Eolian group. Thus there would be talcoid schists of two different ages.

If on the other hand we suppose that the identity of lithological character compels us to suppose that both of these patches of schist, now separated by their position, are of the same age, then we shall have no hesitation in affirming that they are all of the age of the schists capping the limestones ; i. e., newer than the Eolian limestones.

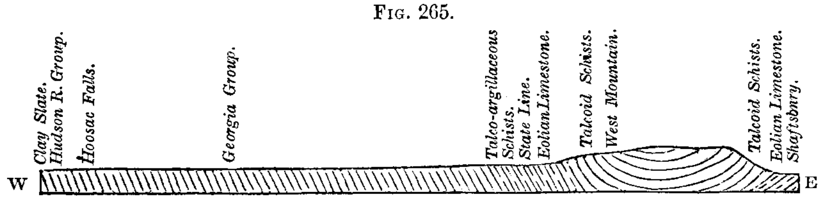
Mt. Eolus, upon which we rely so much for determining the relative positions of rocks, is very similar to Greylock in Massachusetts, which Prof. Emmons uses for a similar purpose. Greylock doubtless is the southern end of the great range (though interrupted) of which Mount Eolus is the northern.

Range, Extent and Thickness.

The disposition of the talcoid schists is into three different ranges, and several outliers. The great range enters the State from Massachusetts at Pownal, and continues north as far as Pittsford. There are three outliers in Pownal, in Manchester and in Dorset, which may have been connected originally with the range. In Rutland there is a curious shaped spur of schist running off from the main group. The second range commences abruptly between Danby Corners and Danby Borough, gradually attenuating till it comes to a point in Clarendon. It is probably a continuation of the Dorset outlier, though having only a third of its width. The third range of talcoid schists extends from Fairhaven to Sudbury, west of the Georgia group of clay slates.

The first rock the traveler sees in entering Pownal from Massachusetts is the small outlier of these talcoid schists. It is a belt about two miles wide, surrounded upon both sides by Eolian limestones. The rocks are mostly the talco-argillaceous and talco-micaceous varieties of the talcoid schists. The outlier, or possibly it may be an independent deposit, passes through the middle of the town, terminating about two miles from the north line, and it almost connects with the main deposit upon the flank of Mount Anthony. The total length of this outlier, both in Vermont and Massachusetts, is about six miles. Its prevailing dip is easterly.

Fig. 265.



Section from Hoosac Falls to Shaftsbury.

Hoosac River has worn away a portion of the schists of the principal range, thus increasing the extent of surface occupied by limestone at the expense of the schists. As the same erosion has acted upon the rocks at Bennington, north of Mt. Anthony, a similar result is there seen. This renders the border line of the schists extremely irregular, as the map indicates. The character and position of the rocks between Hoosac Falls, N. Y., and Shaftsbury Center, may be seen upon Fig. 265. The general feature of this group now, is that of a great range of mountains, the continuation of the Taconic range from Massachusetts, and its gradual western slope. It is a range very steep upon the eastern side, bordering upon the great belt of limestone; and the precipitous nature of the mountains is owing to geological causes. The more easily decomposing limestone passes under

the slates and schists dipping to the west, and therefore will crumble away equally with the slate, and would render the whole about perpendicular, did not fragments of the schists drop down from above and protect the limestone from rapid decomposition. The height of Mt. Anthony in Bennington is 2688 feet above the ocean ; of Equinox Mountain in Manchester, 3706 feet ; of Mt. Eolus, 3298 feet.

Passing into Arlington, we find a break in this mountain range, to allow the passage of the Battenkill River to the Hudson. There is a break in the schists, also, as the river flows over limestone. The limestone probably extends west of Equinox Mountain, also, to connect with the limestones in West Dorset. Thus Equinox Mountain and Red Mountain will constitute a great outlier, unless it be possible that limestone be found between them, when there would be two outliers instead of one. This outlier probably is in the form of a synclinal axis.

An immense amount of rock has been removed between Equinox Mountain and Mount Eolus, even enough to form a valley more than 2000 feet deep.

Mt. Eolus is capped by talcose schist, in the form of a trough; and this mass of schists is isolated from the principal range by erosion. A deep gap has also been made in the formation by the same agent around the whole of the mountain into the west part of Danby. Here the lofty range of mountains, capped with talcoid schists, terminates, but the schist continues on to Clarendon, after a slight interruption, gradually tapering to a point. It is quite clear that this narrow range connects with Danby Mountain, from which it is now separated by a fault. The presence of an interval between the two rocks now is due to erosion. Danby Mountain terminates as abruptly as if it had been broken off square, for a width of three miles. The unusual height of the mountains, and the great thickness of nearly horizontal strata composing them, readily suggests the idea of their elevation. The mountain (including, also, Equinox, etc., to Greylock) must have been raised directly up without pushing the strata either to the right or the left.

The rocks in the deposit running north from Danby, present the same general character as those of the elevated ground. A little west of Barneyville the talcose schist appears dipping at an angle of only 17°, under the limestone, soon it is perpendicular, and then dips east again. It is very highly silicious. Near Danby Corners, it assumes more of an argillaceous appearance, dipping 20° E. The line of the fault is nearly along the general course of the river that rises in Danby Pond. Upon the hill east of the Corners, the rock is argillaceous and slaty, much jointed and slightly plumbaginous. It overlies a dark-colored limestone containing a few encrinites. Upon the same ridge in the north part of Danby, it is schistose and broken up into cuneiform masses—approaching quartzite in its appearance. In the southeast corner of Tinmouth, the same imperfect decomposing rock appears: but it has changed its character very much in the southwest part of Wallingford. No one could ask to see a better characterized talcose schist than this; but it becomes argillaceous near Adair's marble quarry, standing nearly perpendicular.

It is doubtful whether this schist extends into Clarendon, though a ledge of it was found interstratified with quartz rock in the north part of the town. A map of this region, that may afford light upon the position of all these rocks, is given on Plate VIII, Fig. 2.

Although one great range of mountains has terminated, another and more permanent range is found in the west part of Danby running nearly north and south. It is the direct continuation of a range of mountains in Sandgate, viz., Swearing Hill, Minister Hill, Seymour Peak, and Bear Mountain, and composed of the same schists, though not quite as high. The same rocks occupy much of the area of the State, west of Danby.

Numerous details of these rocks in Tinmouth and Middletown are given upon Section V. The range of mountains before mentioned, passes through Danby, Tinmouth, West Clarendon, Ira, Rutland, Pittsford and Sudbury, where it degenerates into a hill, terminating finally in Cornwall. Its eastern limit lies along the west line of Clarendon, and then turns northwesterly, through a district recently ceded to Ira, and, by a small neck on the Rutland and Clarendon line, joins an otherwise isolated deposit of schist running lengthwise through Rutland into the towns north and south, each a short distance. The length of this small range is eight miles, and it is usually less than a mile wide. It is a sort of talco-argillaceous schist, and may be seen to good advantage upon the hill east of the marble quarries in West Rutland, especially where the road to Rutland has crossed it. It appears in numerous ledges south of the latter locality, and in Clarendon less than a mile southeasterly from the springs. The hill may be easily traced into Pittsford northerly—the rock having essentially the same character throughout. A small portion of the same kind of rock is associated with the quartz rock on the east side of Otter Creek, near Mr. Grigg's house.

Bird Mountain in Ira is an interesting locality. The summit is composed of a conglomerate of blue hyaline quartz in a talcose base, the pebbles seldom exceeding a kernel of corn in size. Some metamorphic action has very greatly obscured the dip of the rocks upon the summit. There are planes, probably of cleavage, dipping 57° W., and indications of strata dipping to the west a few degrees. A mile south of the summit, the notes of one observer (Mr. Hager) state that the conglomerate is interstratified with a slate that dips 45° E. It is certain that in the valley east of Bird Mountain (the range runs north and south), the slate dips to the east. Hence it is most likely that this conglomerate is interstratified with the slates. Further south it is said to occur, though not abundantly.—It has not been found north, but the line of its strata passes through an unexplored region.

Herrick Mountain, in Ira, is composed of a talco-argillaceous schist very much contorted. It is in the same range with Bird Mountain.

There are beds of limestone in Ira that are quite interesting. Upon the land of Joseph Tower, three miles southwest of West Rutland, on the eastern declivity of a hill is a bed of fossiliferous limestone. There seems to be some local change in its position, for in company with an overlying slate it dips to the west, while both dip east forty rods north on the line of strike. Upon Ira Mann's land there is a bed of limestone twenty-five feet thick, without fossils. Fossils were also found near the middle of the town, and on the south line of Ira next to Middletown. West of Middletown Center there were also indications of a considerable amount of limestone in the slate. The town is in general made up of green and black clay slate more or less contorted. In most of the territory occupied by the talcose and talcoid schists there is little of interest.

There is a curious gap excavated through the range of mountains composed of the talcoid schist, in Ira. Its bottom is lower than the level country towards Rutland, so that Castleton Brook, instead of running into Otter Creek—as appears the most natural—passes through this gorge in the mountains towards Lake Champlain. It thus forms an excellent passage for the convenience of transportation between the settlers of Otter Creek and Champlain valleys. So unnatural does this chasm appear that we are almost inclined to suppose that it is the result of a dislocation. A hasty examination has not afforded us any proof, however, of the occurrence of different rocks or of a different position of them upon the two sides of the gulf. For all the details respecting the region between Rutland and Lake Champlain, we refer to the description of Section VI.

West of the clay slate of the Georgia group in Sudbury the talcoid schist is found dipping beneath it, forming a belt towards half a mile wide. We have also found it in the northwest and southwest parts of Hubbardton; hence we suppose these ledges, in connection with other layers of remarkably well defined talcoid schist in Fairhaven, to form a single belt of rock, entirely independent of that east of the Georgia slate, unless the two deposits be connected together beneath the Georgia slate. As both bands dip in the same direction, the connected synclinal must be an inverted one.

Thickness. The thickness of the talcoid schists upon Greylock is 2,000 feet. Upon Mt. Eolus they are 498 feet thick. How much has been removed by erosion it is impossible to say. The thickness of the band of schists in Danby, by a rough trigonometrical calculation is 1354 feet. The average thickness of the talcoid schists of the Taconic mountains in Vermont must be greater than 2,000 feet.

Mineral Contents.

Native gold is found in the alluvium derived from the abrasion of the talcoid schists. We have known of its existence in Danby, and the investigations of Mr. Hager show that it is also found in Dorset and Sandgate. Probably, also, the gold in Mt. Tabor, Manchester, Shaftsbury, and Bennington, was originally derived from veins of quartz in these schists. For the particulars respecting the gold in this rock, we refer to the Report upon Economical Geology.

Large masses of milk quartz are abundant in the talcoid schists. It occurs in nodular masses, often mixed with chlorite and the carbonates, and oxyds of iron and manganese. Bowlders of white quartz are very common over the surface which is underlaid by this formation.

Black tourmalin, octahedral iron and pyrites also occur in the talcoid schists.

Organic Remains.

Two species of fossils have been found in Ira, in beds of limestone associated with the talcoid schists. They are a few small encrinal rings, and what resemble an Euomphaloid shell. The specimens are too indistinct for recognition, but are sufficiently plain to allow us to place this formation among the fossiliferous rocks. The specimens are from Ira and West Rutland.

Geological Position and Equivalency.

As stated in the description of the stratigraphical position of the talcoid schists, the question of their geological position depends upon the nature of the disturbing forces. If the Eolian and Equinox range has been elevated to its present position from a great depth, then the talcoid schists capping the marbles belong to the same belt as the talcoid schists on the range of mountains further west, which we have often called the Taconic range. The more we reflect upon the subject, the more evident does it appear that these two bands of rock are the same, and are consequently newer than the Eolian limestone.

If the contrary view is held, it will be necessary to regard this rock as belonging to two different horizons—one below and the other above the Eolian limestone. Upon either theory the age of the schists is determined by that of the Eolian limestone.

Both the Taconic and Silurian theories of the position of these schists, rank them as superior to the Eolian limestone. If they are the magnesian slates, they certainly rest upon the Stockbridge limestone; or if they be regarded as the Hudson River group, then they must rest upon the lower Silurian limestones.

THE TACONIC SYSTEM.

We have referred so often to the *Taconic System* in Part II, that we deem it due to its supporters to present a brief view of its history as a system, and to give an outline of its method in explaining the intricacies of the stratigraphical structure of the rocks in Western Vermont. We shall use the terms which are employed by Prof. Emmons, and shall endeavor to represent his ideas, *as they are published*, as faithfully as though we were the amanuensis of an advocate of the Taconic System. We think that Prof. Emmons would modify some of the statements or terms, were he present; e. g., would substitute the name of talcoid schists for magnesian slate, etc., but we shall not venture to depart from his published statements.

We are not aware that any person except Prof. Emmons claims the credit of the discovery—that the belt of rocks along the Alleghany ranges, denominated Taconic, are sub-Silurian. The first suggestion of the existence of the Taconic system was made in the *2d Annual Report of the Geologists of New York in* 1838. The question is asked, whether the marbles, etc. of the Taconic series ought not to be removed from the primary to the transition class. Subsequently these and associated rocks were grouped into the Taconic system, and claimed to be distinct from and older than the Silurian system. Professors H. P. and W. B. Rogers opposed these views in 1841, before the American Philosophical Society. They drew a section across the different rocks in New York and Massachusetts, exhibiting numerous close anticlinal and synclinal folds, and thus explained the apparent inversion of the dip, which other geologists have ascribed to one general overturning of the whole series. They agreed with Prof. Mather in referring the granular quartz to the Potsdam sandstone, the Stockbridge limestone to the lower Silurian limestones, and the slates and schists to the Hudson River group, all in a metamorphic condition. They had not examined Emmons' sections, which represented the calciferous sandrock, and the Potsdam sandstone, as lying unconformably upon the Taconic slates, but were satisfied in expressing their disbelief of the existence of any such unconformity, because through the whole of the Middle States they had never met with any such discordant stratification. Hence they reckoned the base of the palæozoic series to be the Potsdam sandstone. Similar views were developed by Prof W. W. Mather in his Report upon the Geology of the First District of New York in 1843.

Prof. Emmons developed his Taconic system more fully, in his Report upon the Geology of the Second District of New York, in 1842. The rocks were not found within his district, but were described in general terms, to illustrate some of the most interesting relations of the Champlain group. Quite a full description is given of all the Taconic series. The principal view held in this volume, which has now been changed, was that the gray sandrock (or Oneida conglomerate) capped the Champlain group of lower Silurian strata. That formation, the red sandrock of Snake Mountain, is now regarded by Prof. Emmons as of the age of the calciferous sandrock underlaid by Taconic slates.

In reply to objections that had been urged against the Taconic system, Prof. Emmons continued his examination of the Taconic rocks, and in 1844 published a large quarto pamphlet entitled *The Taconic System.* This volume develops the nature of the disturbances, and describes the extent of the system much more fully and carefully than had been done before. The objections of other geologists to the system are stated and answered, and the volume has a controversial air.

But American geologists were generally arrayed against the Taconic system until 1860. During this interval the anti-Taconic view was presented by Professors James Hall, C. B. Adams, W. B. Rogers, and Sir Wm. E. Logan. All the geologists who investigated the Taconic rocks north of Tennessee were opposed to Prof. Emmons' views. No elaborate works, but simply occasional articles in scientific journals, or abstracts of discussions in Scientific Societies, were published by the opponents. In 1855 Prof. Emmons published in his *American Geology* an elaborate defence of the Taconic system. Here he first ranks the red sandrock series as lower Silurian, and divides the Taconic rock into upper and lower. Subsequently similar defences and further descriptions have been published by him in his Reports upon the Geology of North Carolina, and his Manual of Geology.

The later anti-Taconic views generally adopt the opinions of the Professors Rogers in regard to the synchronism of the lower Silurian and Taconic rocks. They make great use of the doctrines of metamorphism, and apply its principles not merely to the Taconic rocks, but to the crystalline rocks of all New England, supposing that none of them are older than Silurian, and very few are as recent as the coal formation. Emmons seems to discard the doctrines of metamorphism mostly, as if to grant them would be to give up the Taconic system. Perhaps the anti-Taconic advocates have been carrying their theories too far, and may yet be compelled to yield much.

In consequence of the varying limits of the Cambrian and Silurian rocks of Europe, it was difficult to compare the European and American rocks satisfactorily. Hence the first statement was that the Taconic rocks underlie the Potsdam sandstone. We understand Prof. Emmons more recently to claim that the words Taconic and Cambrian (as used by the English Government Surveyors) are synonymous. If the Georgia slates are Primordial, then the upper part of the Taconic system must be Silurian according to the definition.—Perhaps Prof. Emmons will not hesitate to grant this.

The latest aspect of the controversy rests upon the age of the red sandrock and Georgia slates. These were both regarded as Middle Silurian by Prof. Hall and others. The descriptions of the *Oleni* (Barrande) from the Georgia slates called out M. Barrande's views, who unequivocally pronounced the rocks containing such fossils to be equivalent to those containing the primordial zone of life in Bohemia, that is, to the Potsdam sandstone of America. This does not agree with Emmons' views, for he distinctly places the Georgia slates (Taconic slates) unconformably below the Potsdam sandstone. Yet M. Barrande supposes that his views will support the Taconic system.

Immediately following M. Barrande's letters, Sir Wm. E. Logan published a letter to him, announcing the discovery of numerous primordial forms in the Quebec group at Point Levi (equivalent of the red sandrock in Vermont.) In accordance with these discoveries the Canada Survey have given up their former theory that the Quebec group is middle Silurian, and agree with Emmons in calling it lower Silurian. Logan thinks the Georgia slates may be subordinate to the Potsdam sandstone, and may more truly represent the primordial zone in Canada. He differs from Prof. Emmons in not regarding the slate under the red sandrock in Vermont as Primordial, but of the age of the Hudson River group. But throughout Canada, where Prof. Emmons finds many Taconic rocks, Logan finds nothing lower than lower Silurian. Many have supposed that great aid was given by these discoveries to the advocates of the Taconic system; but there is surely little of comfort to them in Sir William's conclusions.

Prof. Jas. Hall opposed these conclusions of Sir Wm. E. Logan, holding that the stratigraphical evidence was in favor of regarding the Quebec group as middle Silurian, just as Logan had held, and that the evidence of Primordial age was not so clearly implied by the fossils, as was the position of the second fauna.

GENERAL CHARACTER OF THE TACONIC ROCKS IN VERMONT.

The Taconic rocks in Vermont are the following, being divided into an upper and lower series.

Upper Taconic Rocks.	*Thickness in feet.*	*Lower Taconic Rocks.*	*Thickness in feet.*
Black slate,	20,000	Magnesian slate,	2,000
Taconic slate,		Stockbridge limestone,	2,000
Roofing slate,		Granular quartz rock, with associated talcose beds,	1,200
Sparry limestone,			25,200

The upper Taconic rocks are the Georgia slate; the magnesian slate includes the talcoid schists and talcose conglomerates; the Stockbridge limestone is the Eolian limestone; and the granular quartz, etc., is the quartz rock of this Report. Lithologically the different members are as follows: The black slate is a clay slate, often highly calcareous. The Taconic slate is an even-bedded, alluminous slate, varying from the finest possible grit to one that is coarse and rather uneven-bedded, and passing into a rock having many of the characters of a sandstone. Its prevailing color is pea green. Its name is derived from that of the whole system, which is derived from the Taconic range of mountains in Western Massachusetts. The roofing slate is only a variety of the Taconic slate suitable for economical purposes. Its colors are every shade of green, chocolate, red, gray and dark brown. It is the Taconic and roofing slates which make up the great thickness of the System. They are best developed in Rutland County.

The term sparry limestone is not a good one, because it can be applied to many rocks belonging to other groups. The distinctive limestone of this member has a bluish color through which there run numerous seams of white calcite, checking it in various ways. Or the rock may be gray and almost black, and it may be traversed by veins of quartz. This member is distinctly characterized by its interstratification in beds from twenty to two hundred feet thick, with the Taconic slates. It is not, therefore, a distinct part of the series, like the Potsdam sandstone in the Champlain group. In general the sparry limestone may be said to be any bed of limestone in the upper Taconic series.

Passing to the lower series, the magnesian slate, the uppermost member, is a species of talcose schist, having an unctous feel, owing to the presence of magnesia. It remains to be proved that the substitution of alumina for magnesia in those specimens which have been analyzed, extends to the whole mass. This slate is generally of a light gray color, with greenish patches. Often it is darker colored, from the decomposition of sulphurets. In the north part of the State, talcose conglomerates and quartz rock form a very large constituent of this member. A few beds of limestone occur in it.

The Stockbridge limestone is silicious and dolomitic in its eastern or lower portions, and is largely composed of pure limestone and marble in its upper portions. There seems to be a gradual change from pure quartz below to limestone above — precisely as the Potsdam sandstone changes into the Chazy limestone, through the interval of the calciferous sandstone. There may be a few narrow beds of slate in some portion of this series. The limestone is generally white, but there is every grade of color between white, black and gray. Occasionally it has a bluish color.

The granular quartz is generally pure, often hyaline, homogeneous, and finely granular quartz rock. It is rare to find any other mineral mixed with the quartz. A very few scattering shales of mica or talc may sometimes be seen. The most prominent varieties of this formation are these: 1. A conglomerate. 2. Brown granular quartz rock. 3. Fine white friable sandstone. 4. Talcose schists and grits of several kinds. Large beds of limestone are connected with the other varieties, which seem to form a part of the series as much as the schists. Whether Prof. Emmons would consider them as the Stockbridge limestone intricately plicated with the quartz rock, or a part of the granular quartz series, we cannot conjecture.

Distribution of the Taconic rocks in Vermont. The western line of the Taconic system begins west of Highgate Springs, at about the east side of Hog Island,—(of course then the Trenton limestone at Highgate Springs is merely an outlier resting upon the Taconic slates.) The western line is in the bottom of Lake Champlain from McQuam Bay in Swanton, passes through the west end of Colchester Point, including probably the rocks on Appletree Point in Burlington. It next touches the shore in the west part of Shelburne. From Shelburne to Orwell, it follows the course of the range of red sandrock, being always a short distance west of the top of a range of mountains, which are capped by Potsdam sandstone and calciferous sandstone (Red sandrock series.) The line turns from Orwell village to the northwest part of Benson, quite near to Lake Champlain. It turns a trifle easterly, passes through West Haven Center, leaving Vermont near the mouth of Cogman Creek. Two and a half miles east of Whitehall, N. Y., east of the mountain, these slates appear exposed in a ravine. This westerly line is the route of a great fault, which extends from Canada to Alabama.

The east border of the Taconic rocks coincides probably with the eastern limits of the talcose conglomerates and quartz rock, as delineated upon the map, running through the towns of Franklin, Sheldon, Fairfield, Fairfax, Westford, Essex, Jericho, Richmond, Huntington, Starksboro, Lincoln, Ripton, Goshen, Chittenden, Mendon, Shrewsbury, Wallingford, Mount Tabor, Peru, Winhall, Manchester, Sunderland, Glastenbury, Woodford, and Pownal. In the south part of the State, this line runs along the base of the principal range of the Green Mountains, but at a considerable distance west of this range as it enters Canada. All the rocks included between these two lines belong to the Taconic system, except the Trenton limestone in Highgate, the red sandrock series, and probably several beds of Eolian limestone in Sudbury, containing Stromatopora, etc.

The black slate shows itself along the western border of the system, and may be seen underlying the Potsdam sandstone unconformably from Canada to Orwell. The prominent localities for displaying the junction, are at Highgate Springs, at many localities between Highgate and North Colchester, at Lonerock Point in Burlington, and on the west side of all the summits of the red sandrock range, between Charlotte and Bridport. In the west part of Benson, and the east of West Haven, this rock appears, uniting the slate beneath the Potsdam sandstone in northern Vermont, with that at Bald Mountain in Greenwich, N. Y.

All of the clay slates west of the Potsdam sandstone range in northern Vermont, which are not the black slate, are the Taconic slate. But the greater part of the Taconic and roofing slates are found east of the sandstone. They are the Georgia slates of this Report, and are consequently located in three different terrains: one in Franklin County, one in Chittenden County, and one in Rutland County.

The sparry limestone is found chiefly in Rutland and Addison Counties, extending from Sudbury to Poultney River in West Haven and Fairhaven. Most of the fossils from the Eolian limestone belong to this rock. Another mass of sparry limestone is seen in Shaftsbury, Sandgate, Pawlet and Ira. This is inclosed by the magnesian slate.

The magnesian slate is in two large deposits, with several outliers. The most distinctive is the southern one, extending from Pownal to Pittsford, lying just east of the Taconic slates. It corresponds exactly to the talcoid schists of this Report. The northern deposit of magnesian slate is the talcose conglomerate of this Report, extending from Lincoln to Franklin. It is largely composed of conglomerates, which are not unknown in the southern deposit.

The Stockbridge limestone, corresponding very nearly with the Eolian limestone of this Report, appears now in two isolated terrains, but they are connected beneath the Potsdam sandstone of Monkton. This limestone occupies the great valleys west of the Green Mountains. We are at a loss whether Prof. Emmons would consider the white limestones, so gently overlying the red sandrock in Burlington and Colchester, as the Stockbridge limestone. We suspect, from its position, it might be regarded as lower Silurian (by his theory) in a metamorphic state, because it so distinctly overlies the Potsdam sandstone and calciferous sandstone of Burlington, although it contains no fossils, unless it be obscure Chætetes and Stromatoporæ. The pure, dove-colored limestone of Colchester might be the Birdseye limestone. We do not regard this limestone as the same with that west of the red sandrock, though their lithological characters are the same. The one is above and the other below the red sandstone; yet, as a profusion of faults and foldings are necessary to sustain the Taconic system, a few might be imported to make this point clear. In that case it would be a bed of limestone in the Taconic slate.

We think that there is a great resemblance between this limestone at Burlington and one described under No. 6 of the gray sandstone, described in Emmons' Geology of the Second District of New York, page 125. There is something wanting in the report, and we cannot decide from the statements whether this limestone is No. 3 of the gray sandstone, or a new number in No. 6, still higher than No. 3. He says: "Of this limestone it is necessary to remark, that it resembles so nearly another limestone, or one which I now suppose belongs to a different period, that it is exceedingly difficult to distinguish them. The one I now speak of certainly occupied the position which I have given it, above the gray sandstone; but there is another in the primary of the Taconic range further east—in the slates of which the range passing through Pownal in Vermont, and Williamstown, Pittsfield and Richmond in Massachusetts, are examples—which resembles it so strongly that I have at times been disposed to consider the two as one and the same rock."

A limestone very closely resembling the Stockbridge limestone, enters Canada from Vermont at Highgate. It is obviously of the age of the Trenton limestone. It was from this rock—which has nothing to do with the Taconic system—that the Canada Survey pronounced the Stockbridge limestone, from its prolongation into Canada, to be the altered Trenton limestone. (See American Journal of Science and Art, New Series, Vols. IX, p. 19; XVIII, p. 195, 196, II. Series.) The true Stockbridge limestone extends no further north than Milton, in Vermont.

The granular quartz is chiefly developed in Vermont in a great range of mountains, some of which are 3000 ft. high. It forms at times the western part of the Green Mountains lying east of the Stockbridge limestone. A smaller portion of the quartz in Rutland County forms an independent range of hills by itself, entirely distinct from the preceding. The numerous interstratifications of quartz rock and limestone, as well as the spurs of quartz rock in Pittsford and vicinity, are very singular, and we will not attempt to surmise a Taconic view of them. The granular quartz terminates in Starksboro, corresponding throughout its whole extent with the quartz rock as described in this Report. It lies at the east side of the system, and rests upon the hypozoic gneiss of the Green Mountains. Divisional planes resembling strata are present in a large part of the formation, insomuch that its true dip is not always a matter of certainty.

GENERAL POSITION OF THE TACONIC ROCKS.

As a general fact, the strata of the Taconic rocks dip to the east, from 20° to 45°. This is true respecting the whole belt from Canada to Alabama. Particularizing the formations in Vermont, we may say, that the invariable dip of the black slate, Taconic slate, roofing slate and sparry limestone, is to the east. The inference would be, therefore, without the supposition of dislocations, that in proceeding eastwardly from the Hudson River group, we ascend one formation in coming to the black slates, two formations in coming to the Taconic slate, and so on, not only to the top of the sparry limestone, but to the top of the granular quartz, and not unfrequently the very gneiss (Laurentian) itself. There must, then, be some explanation of this fact. Why should the new rocks dip beneath the older ones?

The greater part of the magnesian slate dips to the east. But in its eastern portion we discover a beautiful exhibition of the true position of at least two of the members. Mt. Eolus is a pile of nearly horizontal strata, and the layers may, therefore, be assumed to be in their natural position. Here the magnesian slate caps the Stockbridge limestone; so that we may regard the relations of these two rocks to each other as settled. Consequently there must be a fault between the greater part of the Stockbridge limestone and the magnesian slates. The course of this feature we will indicate as nearly as possible. Beginning at the northwest corner of Pittsford, it follows the west boundary of the Stockbridge limestone through Rutland, west of the marble quarries. There is an interruption in the southwest part of Rutland, by a tongue of schist separating the limestone. This is probably due to a minor transverse fault, which has thrust the limestone north of Clarendon to the west of its proper position. If this is so, then, the map must be slightly altered. This transverse fault may be surmised from Fig. 2, of Plate VIII; for there the belt of marble is seen suddenly to change from one side of the valley to the other.

This lateral fault may be traced still further through Clarendon, Tinmouth, Danby, west of Mt. Eolus through Dorset and through Sandgate to Battenkill River. In Danby another transverse fault occurs, which does not seem to have thrust the strata to either side. South of the Battenkill in Arlington and Shaftsbury, the fault is entirely in the magnesian slates, west of the great mountains. The limestone does not rise high enough to appear at the surface. The wearing away of the magnesian slates in the west part of Bennington makes the underlying limestone have of a much greater width than in the towns north or south. The fault continues through the west part of Bennington, west of Mt. Anthony, into the west part of Pownal. Not only are the rocks on the upper part of Mt. Eolus in their original relations, but probably the westerly dip is their normal inclination. For they were deposited upon the western slope of the hypozoic series of the Green Mountains, and dip to the west for the same reason that the rocks of the Champlain group dip east away from their nucleus in Essex County. The prevailing easterly dip of the Taconic rocks is mostly unnatural.

The next question is, what is the stratigraphical relation of the Stockbridge limestone to the quartz rock? In several places in Vermont the limestone dips west away from the granular quartz, as if it was a superior rock. It is in East Middlebury, Pittsford at the Furnace, in Wallingford, in Bennington, and upon the western ridge in Tinmouth and Rutland. But as these cases are offset by a greater number of cases where the order seems to be different, we may step over the boundary of the State three or four miles, where we shall find a case of apparent naturalness in the order of strata, like Mt. Eolus. It is upon Oak Hill, in Clarksburgh, and Greylock in North Adams, Massachusetts. The granular quartz rests upon the protogine of Oak Hill and dips towards Greylock. It points beneath the limestone upon Greylock, and at the west base of the mountain it distinctly runs beneath the Stockbridge limestone. (See Plate XV, Fig. 5.) Greylock, then, is composed of granular quartz, Stockbridge limestone, and magnesian slate, all in their natural order apparently.

Considering the granular quartz as subordinate to the Stockbridge limestone, then we have reason for supposing the existence of another long fault, at the line of the junction of the two rocks, from Pownal to Starksboro. There may not be. a fault between the western range of quartz rock and the limestone, for the latter may fold over the former, even though the fold be inverted.

There is some evidence in Vermont to show that the Taconic and roofing slates overlie the magnesian slate, although it is rather weak, without involving theories. From Sudbury to Fairhaven there is a narrow range of magnesian slate, which of course dips east, and underlies the Taconic slates, etc. May not the magnesian slate have been lifted up with these slates upon its back? If so, then the Taconic slates must be the newest. But one more argument may be adduced. The Taconic slates appear to dip beneath the magnesian slates upon their west side. Therefore if this is the true position, they must appear upon the east side of the magnesian slate, if they belong beneath it. But unequivocally the magnesian slate is underlaid by the Stockbridge limestone, and that by the granular quartz. Hence we have these two horns of the dilemma—either the clay slates belong beneath the granular quartz, or above the magnesian slate. The former horn certainly cannot be taken, consequently there is but one horn left; that is, the Taconic slates are newer than the magnesian slates.

It is important to determine the upper limit of the Taconic system, and ascertain what rocks overlie it. Fortunately in Vermont and vicinity there are beautiful examples of the junction of the Taconic and Silurian systems. Go to Whitehall, N. Y., in sight of Vermont, where the opponents of the Taconic system have derived so much comfort. The Potsdam sandstone there rests directly upon the Laurentian rocks, unconformably, for it is by the unconformability alone that we can determine the limits of the two systems. (See description of Fig. 168.) The anti-Taconic theorist says, what can you mean by asserting the presence of a system of rocks 25,000 feet thick between the Potsdam sandstone and the Laurentian system, when there is not a single foot of it at Whitehall between these two systems! Why, we mean, says the Taconic advocate, precisely what you would say of the relative position of the Champlain clays to the Potsdam sandstone and gneiss; and on the very same ground, too, in Whitehall. You admit that the Champlain clay rests upon both the sandstone and the gneiss. Why does not the sandstone intervene between the clay and the gneiss? Simply because the sandstone cannot cover the gneiss everywhere, owing to the laws of the formation of rocks. The rocks do not surround the globe in concentric coats of sediment. Each system has its own locality. Consequently there must be some line where rocks of two different ages unite. What now is there to hinder a subsequent deposit to be placed, so that it shall cover the edges of the two different formations? Indeed it is an admitted fact that the clay covers both the gneiss and the sandstone. And all that is maintained in respect to the relations of the Potsdam sandstone to the Taconic and Laurentian rocks is, that it covers the edges of both, where they unite. The Taconic rocks were deposited in the great valley between the Laurentian rocks of New England and New York. The western edge must be somewhere. The top of the highest member, that is, the western edge of the system, is about three miles east of Whitehall. After the deposition of the black slate, the Potsdam sandstone is to be laid down. Where will the currents deposit the sand? Obviously very near the black slate, the last band formed previously; just as the Trenton limestone is always formed near the Chazy limestone. So the Potsdam sandstone was laid down upon a floor partly of Taconic, and partly of Laurentian rocks, and near the highest member of the Taconic system.

Those who wish, will find the junction of the Potsdam sandstone and black slate east of Whitehall. Go two or three miles east of the village of Whitehall, upon the east side of the mountain, and the immediate line of contact is exposed in a deep ravine. Thus the sandstone is merely an outlier. There is another similar exposure of the calciferous sandstone and the Taconic slate, near a church three miles east of Whitehall, in a deep ravine. The sandstones dip 5° or 6°E., and the slate 30° or 40°E.

Passing into Vermont there are three localities of special interest, showing the junction of the Taconic rocks with the Potsdam sandstone and the calciferous sandstone, viz., in Orwell, Snake Mountain and Highgate Falls. The discovery of *Conocephalus* in Highgate as long ago as 1847, by Prof. Adams, and the primordial fauna at Point Levi, in Canada, ought surely to convince all, that the red sandrock series is equivalent to the Potsdam sandstone and calciferous sandstone.

In going from Mount Independence, to a little east of Orwell village, the following is the order of rocks passed over: Calciferous sandstone, Trenton limestone, calciferous sandstone, black slate and sparry limestone, all dipping east. Consequently there must be two fractures, one to bring up the calciferous sandstone above the Trenton limestone, and another to elevate the Taconic above the level of the Silurian rocks. Prof. Emmons has given a figure and description* of this section, the latter of which we will quote:

" With only a superficial examination, they [these three limestones] would be regarded as one rock, belonging to the same period. On a careful examination, however, it is clear that the eastern mass rests on a greenish slate, and by going east a short distance, it is plain enough that a slate also overlies it [the most eastern limestone, or sparry limestone], so that it is inclosed between beds of slate, and in this respect is similar to the limestone which lies in the tunnel of the Western Railroad near the State line [Mass.], and which belongs to the slate group, as is clearly proved by observation. Having determined that the eastern limestone at Orwell lies between beds of slate, our convictions it seems should be, that it is not lower Silurian, nor Trenton, nor either of the masses into which the lower Silurian limestones have been divided. But what is the limestone on which the village is built? To determine this question, I traced it northward, keeping it in view for a few miles, and then turned directly west towards the lake. On passing over two or three rocky terraces composed of this rock, I came directly upon the Potsdam sandstone which cropped out from beneath this silicious limestone, and over which I had passed, and which I had traced from Orwell. The result of this examination proved that the rock at Orwell, which seemed to join on to the sparry limestone between the slates, is the calciferous sandstone. The two limestones might therefore be confounded, but, without the aid of a fossil, the geological formation to which the calciferous sandstone belongs is proved by simply determining its relations, and at the same time it is also proved that another limestone of a different period cropped out very near it, and might have been confounded with it. It proves, too, the fallacy of the doctrine that the lower Taconic rocks, or the lower limestones, are but altered Silurian: we have two limestones of different ages together — one rests on the Potsdam sandstone, and is of the Silurian age; the other on slate, and belongs to the Taconic system. The theory of plications and folds it will be seen, will not explain the phenomena or the facts. It is not even a plausible hypothesis, when offered in explanation of the phenomena I have related. I have been unable yet to detect fossils† in the sparry limestone of Orwell, but its condition is as favorable for their existence as in the calciferous sandstone. This locality proving the existence of a limestone which cannot be placed in coördination with any of the limestones of the lower Silurian, throws the burden of proving the period to which it belongs on other shoulders, provided it does not belong to the Taconic system."

Prof. Emmons thinks that there are "four dislocations on this section; and the order of arrangement, beginning with the limestones, is such that we pass, by successive steps, from the oldest to the newest, terminating with those on the lake."

*American Geology, Part II, pages 83, 84.

†Obscure specimens of *Stromatopora*, *Chætetes*, and encrinal stems have since been found in it. C. H. H.

We have already described the rocks of Snake Mountain in full (See Fig. 167), but will quote from a subsequent page of the American Geology, Prof. Emmons' views of the order of rocks there:

" The rocks between the lake and base of the mountain are lower Silurian. In the ascending order [at the base], the rocks are calciferous sandstone, Chazy and Trenton limestones." The slates are not Utica or Hudson River, but black slate. There are two faults, which we have indicated in Fig. 167. The rock on top is the calciferous sandstone. The fractures "may be traced in the direction of the mountain axis, four or five miles. The dip of the Silurian rocks is from ten to fifteen degrees; of the taconic slates, twenty-five to thirty degrees. At the northeast base of the mountain, perhaps three-fourths of a mile from its summit, the slates crop out again, beneath the calciferous sandstone.

" The summit of the mountain is calciferous sandstone, and is exposed in a perpendicular mural precipice for four or five miles. The debris and fallen masses from this bold front generally conceals the underlying slate, but it crops out beneath it at one or two places, while on the north side the whole slope is exposed, and consists of one mass of slate from the calciferous sandstone to the bottom of the mountain.

" The calciferous sandstone in this region is often red or chocolate color, especially the inferior part of it. The gray variety at Burlington graduates into the red; and the Potsdam, which is used as a flagging stone, at Burlington and other places, is usually brown or chocolate colored also. But the blue and gray with a sparkling luster are found in the masses composing the mural wall at Snake Mountain. The junction between the Taconic slate and Trenton limestone and its upper slates, or the Chazy limestone on the west flank of the mountain, has not been observed.

" The foregoing statements respecting the relative position of the rocks of this mountain seems to be all that is required to establish the inference I have drawn from them. I need not dwell on the error which has been committed [by myself and others] in regarding the chocolate-colored rock the Medina sandstone, or attempt to show that the plication theory will not adjust the rocks so as to make the black and greenish slates, the Utica slate or Hudson River group. It is one of simple dislocation, where the older rock on the east side is elevated vertically higher and above a newer series on the west. The rocks, in this case, are not engulphed upon the west side; all the phenomena seem to prove that the whole mass composing the mountain was raised vertically, but the east side was separated from the west by fracture, and elevated above it. The series between the mountain and the lake occupy a much lower position than those upon the flank of the mountain, proving that the latter have been broken from the former and elevated above them. We find in Snake Mountain, a fact of common occurrence, a fracture at the base of the ridge or mountain, and another running through it. Bald Mountain is another instance of this kind. In fine, with respect to Snake Mountain, the position of the mass on the top of the mountain [Red sandrock] and which covers the eastern slope, proves that it is an overlying mass, and an inspection of the junction of the inferior beds which often jut over and beyond the slate immediately below, proves that it was deposited upon the slate; and as the two are unconformable, both in the amount of dip and direction, it is also evident that they do not belong to one group or series. At this place the former is the base of the Silurian system. It is very silicious generally, and might be called a sandstone, yet it is rather a mass intermediate between the calciferous sandstone and the Potsdam sandstone. It is the same rock as that at Burlington, and at Sharp Shins [Lonerock Point], two miles northwest of Burlington, where the same black slate crops out as at Snake Mountain. Those who wish to satisfy themselves of difference between the Hudson River group and the slate beneath the calciferous of this mountain, should explore the north end of it, where they will find a mass of slate from top to bottom laid bare by a small stream which takes its origin immediately beneath the jutting calciferous sandstone, and which by this little stream has been undermined for centuries, and from which huge blocks have been, and are still, broken and carried down the mountain's side, and are found distributed far and wide upon its northern and western sides. This slate is uncovered in a continuous mass, between 700 and 800 feet thick. I was unsuccessful in a search of a few hours for fossils, and yet it is similar to other exposures where I have found graptolites."

The other locality referred to is at Highgate Falls, where the calciferous sandstone overlies the black slate. The Missisco River passes through a gorge, just below the village, where a junction of the two may be seen at low water. The rocks both dip in the same direction, but the angle of inclination of the slates is greater than that of the sandstone. The calciferous sandstone appears to rest in an irregular trough in the slate, and also upon its edges. The strata of slate in some places are bent at the junction, owing to forces which have been communicated to the rocks. And there seems to be an anticlinal in the slate, while the sandstone rests upon its top upon both sides of the axis. This fact makes it certain that the sandstone and slate form two distinct groups of rocks, viz., Silurian and Taconic.

Similar sections might be multiplied, but it is clear that the calciferous sandstone and Potsdam sandstone overlie the black slate of the Taconic system. Hence the upper limit of the system is well defined.

THE ORIGINAL POSITION AND SUBSEQUENT DISLOCATIONS OF THE DIFFERENT MEMBERS OF THE TACONIC SYSTEM IN VERMONT.

Supposing that there was but little disturbance of the strata until the close of the Taconic period, the original position of its members is quite plain. The Laurentian rocks of the Green Mountains were the ones upon which the Taconic rocks were placed, just as the Silurian rocks encircle the Laurentian rocks in Northern New York. The first rock deposited rested upon the western flank of the Green Mountains, dipping westerly. Probably the whole of the great valley west of the mountains was underlaid with this rock. Upon this was deposited the Stockbridge limestone, then the magnesian slate, and so on to the black slate. All these rocks had a gentle westerly dip. It is not to be supposed that each member should entirely cover up all those below it, any more than that the Oneida conglomerate in New York should conceal the Trenton limestone so that no traces of the latter could be found. Neither is it necessary to suppose that the lower members underlie the whole area covered by the upper members. In these respects the parallel between the New York and Taconic systems is perfect.

But the Green Mountain range begins very early to press against this system of rocks, or in other words the lateral pressure from a southerly direction was more thoroughly exerted in this region than at any other point between Lake Champlain and the ocean.—Instead of a series of beautiful curves, as appears elsewhere, the great pressure seems to have broken up the strata, so that the force relieved itself by lifting up mountain masses and crowding them together, at the same time giving an easterly dip—perhaps inverted—to most of the members. Such masses of the strata as Mounts Eolus and Equinox seem to have pushed up, just as a wedge may be conceived to be forced back from its position by pressure against its sides. As the result of this pressure the granular quartz would be crowded high up on the west flank of the Green Mountains, and form a high ridge. It might often be elevated higher than the rocks stratigraphically above it. At the same time some of these fragments may have sunk instead of rising.

Prof. Emmons supposes that in general there are four or five of these masses of strata or segments, separated by faults. In general the segments are composed of older and older rocks, as we travel east from the Silurian rocks, though without the knowledge of dislocations we should suppose that we were rising higher and higher in the Silurian series. There may be a repetition of rocks often, as is probably the case in the Stockbridge limestone at Middlebury and Cornwall. It should be observed, also, that the force which breaks the continuity of the strata exerts its maximum power nearest the Green Mountain range—and hence may be regarded as proceeding outward from it; and hence, too, the frequency of fractures is proportioned to the nearness of the strata to the disturbing range. Thus, near Williamstown there are five well-defined fractures within a distance of two miles.

Three difficulties are experienced in tracing out the connections of the Taconic rocks. 1. The numerous disturbances of the strata. 2. Vast amount of denudation, which has crowded rocks unequally, owing to their different capacity for resisting decomposition. 3. Obscuration of lines of union between different rocks by alluvium. The most difficult point to find distinctly exhibited, is the dislocation between the Taconic slates and the Hudson River slates. As the rocks are similar, and much crushed at the line of contact so that all fossils are obliterated, it is very difficult to draw the exact line of demarcation. In general the Taconic slates have been elevated higher than the Hudson River group. Hence this elevation, and all other disturbances, must have been subsequent to the deposition of the Hudson River group.

Dikes. It is remarkable, in a region so thickly strewed with faults, that dikes are not more common. We see them in Vermont in the marble upon Mt. Eolus, Danby Mountain, in the limestone at North Dorset, in marble quarries in the southwest part of Rutland, and a number in Chittenden County. Dikes are not as numerous in general in the Taconic as the Silurian rocks, except upon Pottier's Point, in Shelburne. It is not absolutely certain, however, that these slates are Taconic.

Organic Remains of the Taconic System.

Every member of the system is fossiliferous in Vermont, though the remains are often scanty. The granular quartz holds the oldest animals in North America, and probably the oldest relics of life, even older than the *Oldhamia antiqua* of Murchison. As the base of the Palæozoic rocks, it is interesting, because we can obtain some glimpse of the rudimentary condition of the earth at this partially finished stage of its history. The conditions under which the granular quartz was formed must have been peculiar—a condition of higher temperature, and greater energy in the action of chemical forces.

The most striking points in the life of the Taconic period are: 1. The simplicity of the organization of the animals; and 2. The very small number of individuals that existed. The animals belong to the Radiata, Mollusca, and Articulata, and are represented by some of the lowest types in all these sub-kingdoms. The Articulata appear only in the uppermost members. If animals had been abundant in the Taconic ocean there is no reason, from the metamorphic character of the rocks—at least the most important of them—why they should not have been preserved. Hence there is a general conformity between the life of the Taconic system, in America, and the Cambrian, in Europe.

The fossils of the granular quartz in Vermont, are obscure fucoids, *Scolithus linearis*, crinoidal columns, a *Lingula*, a mollusk resembling *Modiolopsis*, and a small Orthoceratite. Out of Vermont only the Scolithus and two species of sponge have been found—the *Palæotrochis major* and *P. minor*.

In the Stockbridge limestone in Vermont, several genera of corals occur, viz., *Stictopora*, *Chætetes*, *Stromatopora*, *Zaphrentis*, and one shell, resembling *Euomphalus*. There are at least two species of encrinites. No fossils have been found in this limestone elsewhere.

The magnesian slate, or rather a bed of limestone belonging to the series, presents us with an obscure disciform shell, and a few encrinal remains.

In the upper part of the system, fossils are more abundant. There are numerous graptolites, *Lingulæ*, and *Oboli*, and three genera of trilobites. In Vermont there are fucoids, graptolites, annelid trails, and four trilobites in this division. Those which have been named are the *Graptolithus Milesi*, *Barrandia Thompsoni*, *B. Vermontana*, and *Bathynotus holopyga*. Prof. Emmons regards all the trilobites as *Paradoxides*, and two of them he names *P. brachycephalus*, and *P* (?) *quadrispinous*. Still another trilobite in Vermont, is the *Atops punctatus* of Prof. Emmons.

PRESUMPTIONS IN FAVOR OF THE TACONIC SYSTEM.

1. *Its similarity to the Cambrian System in Europe*. The rocks in Europe, particularly on the British Islands, are abundantly fossiliferous and rarely metamorphic as far as the base of the lower Silurian. In the Cambrian, the rocks exhibit traces of metamorphic action, but not enough to obscure organic remains, of which but few relics are found.—Below the Cambrian are the metamorphic hypozoic rocks. The correspondence of the lower Silurian, Taconic and Laurentian rocks of America, to the lower Silurian, Cambrian and hypozoic of England is perfect. But on the contrary supposition, that the Taconic system exists in America only in imagination, then we have no similarity between the corresponding American and European strata. The thickness of the Cambrian in Wales and the Taconic in New York and Vermont corresponds. 2. Therefore, we have a presumption that the old doctrine of the Laurentian age of the New England azoic rocks is correct. The doctrine of metamorphism as advocated by many authors becomes extravagant. How much more in accordance with the analogies of European strata to suppose that the chief locality of the action of metamorphism was in the Laurentian period, and that cases of subsequent thorough alteration are exceptional! The theories of the Laurentian age of the azoic rocks of New England, and the Cambrian age of the Taconic system, stand or fall together.

3. *The Taconic Rocks are physically unlike the lower Silurian*. There is a general correspondence in the kinds and order of rocks in the two systems, namely, a sandstone, a limestone and a slate. But the granular quartz is totally unlike the Potsdam sandstone, the marbles and limestones are unlike the lower Silurian limestones. All the marble of the lower Silurian rocks is in the Black River limestone twelve feet thick. This is near the middle of the limestones. The Stockbridge marbles in Vermont are near the top of the limestones, and are more than a hundred feet thick. There is nothing like the magnesian slates in the Hudson River group.

4. *The Taconic System underlies the lower Silurian*. It would be a waste of time to dwell upon this argument, as its points have already been stated. It is completely convincing by itself.

5. *The thickness of the Taconic and lower Silurian Rocks do not agree*. The lower Silurian rocks in Vermont cannot be 2,000 feet thick. The Taconic rocks cannot be less than 25,000 feet thick. The maximum of the Hudson River group in Pennsylvania is 6,000

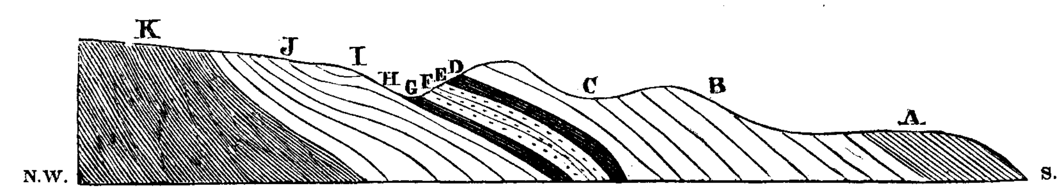
feet, as given by H. P. Rogers. The thickness of that part of the Taconic system which is supposed to correspond to it is not less than 22,000 feet thick.

6. *The Organic remains of the Taconic and lower Silurian Rocks are entirely different from one another*. "The species of fossils differ from the Silurian types; that is, the species are different, and they are not intermingled with the well known Silurian types, for of the latter none are yet known, and this last fact(?) is a significant one. If the beds which contain fossils contain none which are Silurian, what are we to infer, especially if this is a general fact; certainly, that if fossils are to have weight in determinations of this kind, it goes strongly against the doctrine that the series is Silurian. If it is an established doctrine that rocks which are separated in vertical space, and also in time, will be characterized by different fossils, then that doctrine should govern our opinions. If we can account for the absence of fossils in a fossiliferous series, on established principles, their absence becomes of no account in questions of age; but when the fact is general, and it prevails for a thousand miles, it becomes significant. A fossil period will furnish fossils somewhere on lines so extended—and if on lines thus extended they are not found, then we are justified in the belief that the period was not one of life and vitality." (*American Geology*, Part II, pp. 121, 122.)

UPPER HELDERBERG LIMESTONE.

We describe under this head two belts of limestone; one in Massachusetts, and the other extending from Vermont into Canada, and exhibiting its peculiarities best out of the limits of the State.

Fig. 266.



Section in Bernardston, Mass.

Explanation of Fig. 266.

A Clay slate.
B Quartz rock and quartzose conglomerate.
C Quartz rock.
D Clay slate.
E Magnetic iron ore in F.
F Encrinal limestone (Upper Helderberg ?).
G Clay slate.
H Quartzose conglomerate.
I Quartz rock (slaty), dip west.
J Quartz rock, dipping east.
K Clay slate.

The first deposit of limestone which we will notice is not located in Vermont, but is so intimately connected with the continuation of rocks from Vermont, that it must be briefly described. It is in Bernardston, Massachusetts. The clay slate of Vernon and Guilford, when extended a few miles southerly, is associated with limestone, quartz rock, and magnetic iron ore. The limestone does not appear in Vermont; but the overlying quartz rock is developed in Vernon, immediately overlying the clay slate, unconformably, we suspect.

The position of these rocks in Bernardston may be understood from the section in Fig. 266, which crosses the rocks northeast and southwest, or at right angles to their strike.

Commencing at the southeast end of the section we find a small knob of distinct clay slate, with a strike of N. 52° E., and a dip of 30° E. It is thicker bedded and harder than most clay slate. This is at A. Before reaching the limestone we pass over, at band C, quartz rock and quartzose conglomerate. The first ledge west of A, has the strike N. 65° E., and dips 29° E. Still further west, at a quarry where the quartz rock is very much divided by joints, the strike is N. 50° E., and the dip 25° E. A few rods south of the limestone this quartz rock is mostly hyaline, and has the strike N. 60° E., and the dip 52° E. Twenty rods north of the limestone, quartz rock, which we suppose to be the same as C in the figure, dips 60° W. Hence we have sometimes doubted whether the true position of the limestone is given in the figure.

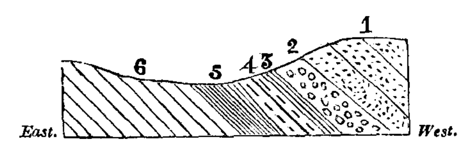
This quartz rock is very distinctly stratified with some mica interlaminated, and is often jointed. It extends northeasterly into and through Vernon, but nowhere, save in Bernardston, have we found any clay slate overlying it, as at A. The great body of the slate lies to the west and below the quartz. The quartzose conglomerate at B is somewhat insulated from the other rocks, but its relative position to the others we suppose to be correctly represented. The semi-crystalline limestone, F, which is the most important rock upon the section, is both overlaid and supported upon very thin bands of clay slate, each not more than from four to six feet in thickness. The limestone is more than ten feet thick. The rock is highly crystalline, and so are the fossil remains. The larger relics have an annulated appearance, but the specimens are largest at one extremity, and sometimes an inch in diameter. They are obscure. Perhaps they belong to the Cyathophylloid family of corals. But there is a small species of encrinite present, concerning whose nature there is no question. This limestone embraces a bed of magnetic iron, some of which has passed to the condition of limonite, not differing in appearance from bog ore. The limestone runs northeast and southwest, dipping 16° S.E. It is composed of carbonate of lime, 98.38; peroxyd of iron, 0.62; and silica, 1.00.

Only a few rods N.W. of the limestone there is a rock made up of fragments of quartz and slate, whose position seems to be this: strike, N. 5° W., dip, 25° W. A little further there is a slaty, dark-colored quartz rock, with the same position. Next there is a ledge of quartz rock, J, dipping east. The length of the section thus far is about eighty rods. Nearly a mile west of the limestone clay slate shows itself, running N. 3° W., and dipping 60° E. No rock shows itself between, but we have extended the clay slate nearly to J, because from other sources it is known that this rock occurs here. This band of clay slate is several miles wide, and is the range which enters Vermont in Guilford and Vernon. A few rods southeast of the section, the Connecticut River sandstone appears, with a westerly dip.

Professor James Hall has examined the fossils from this bed of limestone, and finds them to resemble the large encrinites of the upper Helderberg group of New York. He thinks that this limestone is certainly no older than upper Helderberg, and yet that the encrinal remains, though unique, are not sufficiently characteristic forms of life to be infallible guides in the identification of strata.

The reason why we have little doubt of its Devonian character, is its stratigraphical relations to the other belts of limestone in northern Vermont. Like this that is very near the top of the clay slate series, and is overlaid by a conglomerate. These two deposits of limestone occupy the same positions upon the opposite sides of an anticlinal axis. The axis is in the calciferous mica schist, which is overlaid by clay slate. In the upper part of each band of clay slate occurs the limestones. If now the Memphremagog limestone is to be considered from palæontological evidence upper Helderberg limestone, then the Bernardston limestone should be ranked with it. The other belt of upper Helderberg limestone is much more extensive. Just over the Vermont line near Jennings' Hotel, upon the west side of Lake Memphremagog, it is developed better than in Vermont, where also the only fossils in it we have seen have been found. The same belt of limestone runs into Vermont, and may be seen in Newport, Coventry, Irasburgh, Albany, Craftsbury and Wolcott. Its northeasterly extent in Canada is unknown to us.

Fig. 267.



Section at Owl's Head.

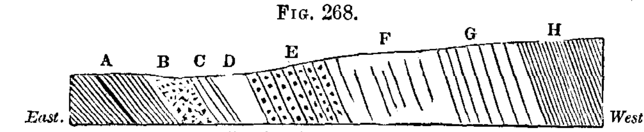
Explanation of Fig. 267.

1 Talcose schist, middle range.
2 Coarse conglomerate.
3 Clay slate.
4 Upper Helderberg limestone.
5 Clay slate.
6 Calciferous mica schist.

Fig. 267 represents the order of rocks at Owl's Head and vicinity. The section extends across Lake Memphremagog to show the relations of the limestone to the calciferous mica schist. The rocks all dip west, and thus this fossiliferous limestone is seen to plunge under the great range of talcose schist. It is not the usual position for inverted strata; for in New England and Canada, such strata invariably dip to the east. On this account the position of the Memphremagog limestone is extremely interesting; for upon its age depends perhaps the age of the talcose schist. No one could ask for a clearer case of superposition than that of the talcose schist over this limestone. If the position of the strata is abnormal, the irregularity is occasioned by plication, and not by faults. The dip of the limestone is 53° W., and the strike N. 35° E. The most important fossils in this rock are *Atrypa reticularis* and a *Zaphrentis.*

There is a great thickness of this limestone in Coventry, probably more than 200 feet. At a saw mill in the west part of the town, it is quite dark-colored, rings when struck with a hammer, and is very slaty. It here dips 50° W., and runs N. 30° E. In another place in Coventry it runs N. 40° E., and dips 46° N.W.

Fig. 268.



Section in Coventry.

Explanation of Fig. 268.

A Clay slate.
B Upper Helderberg limestone.
C Clay slate.
D Rocks concealed by drift.
E Talcose conglomerate.
F Bright green talcose schist, with scarcely any planes of stratification: like 1 of Fig. 267.
G Novaculite.
H Common talcose schist.

The Section in Fig. 268 commences at the village of Coventry, and extends west for two miles. The general position of the different rocks is the same as at Owl's Head. East of A is the calciferous mica schist, then comes the clay slate; in the upper part of which is the limestone, and last of all the talcose schist. All have the same westerly dip. The dip of the limestone in Coventry is a little less than at Owl's Head, while the most remote talcose schist has a much higher dip. The conglomerate is less distinct in Coventry at the point of the section, but two or three miles distant it is more distinct than in Canada.

Section XI. crosses this band of limestone in Craftsbury, and is represented in the Cabinet by No. $\frac{11}{158}$. The amount of calcareous matter in it is quite small.

Upon the Berlin side of Winooski River opposite Montpelier, at the bridge joining upon Main Street, there is a bed of limestone in the clay slate, nearly twenty feet thick. It has the same stratigraphical position as the limestone just described, and we think there is little doubt of the continuance of this limestone as far as Montpelier. It dips about 70° W. West of this locality there are other small beds of similar limestone, from a few inches to a foot in thickness.

FOSSILS.

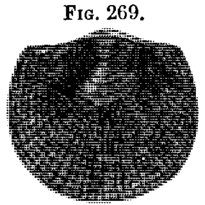
We shall particularize two fossils from Owl's Head, which are of great importance in establishing the geological position of this limestone. They are the *Atrypa reticularis* (Dalm.), and a species of *Zaphrentis.*

Atrypa. Shell impunctate; oval, usually plaited and ornamented with squamose lines of growth; dorsal valve gibbose; ventral depressed in front; beak small, often closely incurved; foramen round, sometimes completed by a deltidium, often concealed; dorsal valve with a divided hinge-plate, supporting two broad spirally coiled lamellæ; spires vertical, closely appressed, and directed towards the center of the valve; teeth and impressions like *Rhynchonella.*

The shells of this genus differ from *Rhynchonella* chiefly in the calcification of the oral supports, a character of uncertain value. *A. reticularis* furnishes the type of the genus.

Fig. 269 represents a view of the ventral valve of a large specimen of *Atrypa reticularis* from the Niagara group of New York. It has certain characters different from the varieties in the upper Helderberg group.

Fig. 269.



Atrypa reticularis.

Professor Hall says of this species: "It commences its existence in the Clinton group; and if we include in one species all shells having these general characters, it extends through all the succeeding groups to the Chemung group, inclusive. In each of these positions, however, it possesses some peculiarity by which it may be distinguished; and the variety from the Niagara group can never be mistaken for that from the lower Helderberg limestones, nor the one from the lower for the one from the upper Helderberg limestones; nor will either of these be confounded with the specimens from the Hamilton and Chemung groups. It is, in fact, much less difficult to discriminate between specimens of this fossil from the different geological positions, than between others which are recognized as distinct species. On this account, I have been inclined to recognize them as distinct varieties at least, and there is much foundation for specific distinction." (*Palæontology of New York,* Vol. II, p. 270.)

The following is a general description of this species, from the same authority, p. 72: "Shell sub-rotund, more or less compressed, sub-truncated above or on the hinge line; valves more or less equal, the beak of the dorsal valve extending beyond the ventral valve, and the latter being deeper and more convex in older specimens; surface marked by dichotomous rounded striæ, which are crossed by concentric elevated lamellæ, giving a reticulated or decussated character to the surface."

The *Zaphrentis* is a genus of Cyathophylloid corals, which are found sparingly in the upper Silurian, but more abundantly in the Devonian series. The specimens from Lake Memphremagog cannot be distinguished from specimens of the same genus from the Eolian limestone in Sudbury.

These fossils were examined by Prof. Hall, who pronounced them to belong to the upper Helderberg group. The *Atrypa reticularis*, and certain species of *Zaphrentis* are common above division D of the Anticosti group, and the former is found in Lower Canada in the extension of the Memphremagog rock, accompanied with other characteristic forms of the upper Helderberg. The Canadian geologists, however, have not defined the limits of the upper Helderberg upon this extension, in distinction from the Niagara group.

The upper Helderberg, as seen on page 54, is in the lower part of the Devonian system. It is better known to some as the Onondaga limestone. It is a remarkably persistent group in its distribution, as it is often developed where both the shales above and the sandstones below are wanting. How remarkable that this limestone can be recognized among these azoic rocks; and especially that it can be traced as far as Montpelier, in the very heart of what, a few years ago, was universally conceded to belong to the oldest series of strata upon the globe! We confidently expect that the progress of knowledge will ere long develop the age of every azoic rock in New England.

PART III.

AZOIC ROCKS.

BY C. H. HITCHCOCK.

We now advance to a description of rocks in which not only all evidences of life are gone, but, also, most of the original structure. That which they now exhibit has been in a great measure superinduced by chemical and mechanical agencies. Stratification and lamination appear to have been produced by original deposition in water. But cleavage, which occurs in slate, is a tendency to split into thin plates, which are parallel, both in dip and strike, over wide areas. The general opinion among geologists is, that it has resulted from powerful pressure, which has extended the particles of the rock and made them separate into layers. The strike and dip of these layers may, or may not, coincide with the lamination and stratification. It would do so if the pressure by which cleavage is produced were exerted at right angles to the stratification; otherwise not, though we must believe that chemical as well as mechanical agency has had something to do with cleavage. The theory of superinduced structures, however, we shall consider in the fourth part of our Report.

To determine the coincidence or want of coincidence between stratification and cleavage is one of the most difficult achievments of practical geology, and demands more time than can generally be given to it in geological surveys in this country. We have not attempted it to much extent in the slates of Vermont; still less have we tried to draw a line of distinction between the foliation of the schists and stratification; for this is a still more difficult work. Hence the strikes and dips which we shall give are those of foliation and cleavage. But we believe that these usually correspond essentially with the stratification. In the fossiliferous clay slates of the western part of the State, as well as in the limestones, we not unfrequently have found the cleavage planes making quite an angle with those of original deposition; but in all those belts of slate interstratified with the more thoroughly metamorphosed schists, the two seem usually coincident. And we think that in this case the plicating force, which had so much to do both with cleavage and plication, acted nearly at right angles to the longer axis of the formations, which would bring the two structures into coincidence. But more of this in another place.

It seems to us, also, either that the term cleavage must be modified in its meaning, so as to embrace not merely the indefinitely thin plates of slate, but the thicker plates which we sometimes meet in limestone and quartz rock, and which cannot be referred to stratification or joints. What objection to saying that cleavage is the superinduced tendency in rocks to split into plates, without limiting their thickness?

We ought to introduce here a definition of slates and schists in distinction from each other. For geologists, after using these terms so long interchangeably, and without a definite meaning, seem to be settling down upon a well-marked distinction. In a slaty

structure, or cleavage, the mass is homogeneous, or of the same composition; in a schistose structure, the ingredients are arranged in alternate layers or folia. In some of the schists, however, such as the micaceous, talcose and hornblendic, the composition is essentially homogeneous, but they are crystalline, and clay slate and shale are never so. Hence we think that the definition ought to be modified so as to describe slate as homogeneous and uncrystalline, and schist as heterogeneous and crystalline, with the ingredients usually in alternating layers. Shale is merely indurated clay, or an earlier condition of slate.

Besides the above structural arrangements, which are confined to the stratified class, we find another set of divisional planes in all the formations, stratified and unstratified.—These are called *joints*. They traverse rocks in all directions, though they show a strong tendency to parallelism often over wide areas. In the unstratified rocks they are rarely parallel; but when they are so, they give to the ledges the appearance of stratification.—In the stratified rocks they sometimes run parallel to the strike or direction of the elevated edges of the rock, and are then called "strike joints." Others cross the strike, generally at a large angle, so as to divide the rock, in connection with the planes of stratification, into rhomboidal or even cubical forms.

Joints like cleavage and foliation are a superinduced structure commonly supposed to be produced by the manner in which the beds are consolidated, or by subsequent mechanical force. But we shall discuss this subject under the unstratified rocks. The importance of joints in practical operations is too obvious to require illustration, since without them the blasting out of unstratified rocks would be almost impossible, and that of the stratified quite difficult.

The following is a list of the Azoic rocks in Vermont, which we shall describe in the order below:

GNEISS.
HORNBLENDE SCHIST.
MICA SCHIST.
CLAY SLATE.
QUARTZ ROCK.
TALCOSE SCHIST.
SERPENTINE AND STEATITE.
SACCHAROID AZOIC LIMESTONE.

GNEISS.

The essential ingredients of gneiss are quartz, feldspar and mica. The feldspars in the gneiss of Vermont are of two kinds; the potash feldspar Orthoclase, which is the most common, and the soda feldspar Albite. No other species of feldspar has been recognized within the State. The mica is the common mica or Muscovite. A large part of the gneiss of Vermont is deficient in feldspar. Those component minerals are arranged more or less in folia, and the rock is stratified. The *Gneiss Formation* consists of gneiss and its varieties, with a few associated rocks, generally in the form of beds. There are three belts of gneiss in the State; one along the axis of the Green Mountains, the second in patches along Connecticut River, and the third is in the southern part of the State, lying between the other two.

Lithological Characters of the Gneiss and Associated Rocks.

The following are the varieties of gneiss and associated rocks in Vermont:

1. Gneiss, both schistose and laminar.
2. Granitic gneiss.
3. Hornblendic gneiss.
4. Porphyritic gneiss.
5. Epidotic gneiss.
6. Calcareous gneiss.
7. Talcose gneiss.
8. Feldspar and quartz.
9. Hornblende schist.
10. Beds of quartz rock.
11. Beds of dolomite and limestone.
12. Beds of steatite, serpentine and associated rocks.
13. Talcose and cholorite schists.
14. Mica schist.
15. Eurite.

The first eight are properly varieties of gneiss, the last seven are properly associated rocks, of which numbers 9, 11, 12, and 14 will be fully treated of in the descriptions of these rocks hereafter in this part of the Report.

I. GNEISS.

The gneiss of Vermont is quite variable in its appearance, just as it is elsewhere. The variation may be in the schistose or laminar structure, in thepredominance of one of the composing minerals, or in the coarseness of the grains. The gneiss is generally schistose, or made up of folia of the different minerals. Each layer may be composed of subordinate folia, or else the whole layer may be entirely composed of a single mineral. When the layers are severally composed of aggregates of the same mineral, the gneiss may be called laminar. Layers of hornblende are often connected with this variety, insomuch that in many instances the rock may be regarded as composed of alternating layers of gneiss, mica schist, and hornblende schist.

In some parts of the gneiss, black mica is the most abundant mineral, and thus the rock is mostly black mica; e. g., No. $\frac{5}{56}$ from Cavendish. Or the mica may be green instead of black, as in No. $\frac{5}{68}$ from Cavendish. Or the feldspar may be green, as in No. $\frac{4}{50}$ from Townshend; etc. The firmness or coarseness of the crystals composing the gneiss, presents a great number of varieties to the eye; but none of these are worthy of specification. The prevailing color of the gneiss is grayish white, but there are multitudes of exceptions.

The greatest peculiarity in the gneiss of Vermont, and more particularly in the range composing the Green Mountains, consists in the deficiency of feldspar; so that the rock is often mica schist, or at the best, feldspathic mica schist. Because of this peculiarity, Prof. Adams called this range of gneiss the *Green Mountain gneiss*, in order to distinguish it from true gneiss. We do not think it necessary to carry out this distinction upon the map, partly because of the multiplication of colors necessitated by the alternations of the two kinds of gneiss, but chiefly because true gneiss is the prevailing rock upon this belt. It is chiefly developed, however, in the south part of the State, while the feldspathic mica schist is more abundant in the north part of the State.

II. GRANITIC GNEISS.

This variety approaches very near to granite, and hand specimens of the two rocks cannot be distinguished from each other. Even large areas of the rock itself can scarcely be distinguished from granite. But a careful examination will generally disclose an obsolete parallelism of the mica. In accordance with the views adopted in this report respecting the origin of granite, it will follow that the difference

between granitic gneiss and granite is but slight. For if gneiss by metamorphic action may become granite (or the reverse, according to Scrope), may *fuse into it*, as it were, the stage of the process immediately preceding the granite state, cannot be far removed from the granite itself. Examples of granitic gneiss may be found at the village of Jamaica, and in the greater part of the gneiss along Connecticut River. It is a question whether the so-called granite between Waterford and Maidstone, is other than granitic gneiss.

III. HORNBLENDIC OR AMPHIBOLIC GNEISS.

Hornblende is exceedingly common in gneiss. When the amount of hornblende present is not great enough to constitute hornblende schist, but enough to give character to the rock, we call it hornblende gneiss. The hornblende is usually disseminated in black foliated masses through the gneiss. It is most abundant in the vicinity of hornblende schist; and that is most abundant in the south part of the State.

IV. PORPHYRITIC GNEISS.

The peculiarity of this variety consists in the method in which the feldspar is distributed through the rock. It occurs in rounded or ovoid masses, like small pebbles. These masses are generally a part of a single crystal, and are permeated by the normal cleavage of the orthoclase feldspar. Often the rounded masses would be mistaken at a distance for pebbles. This variety is poorly developed in Vermont. The localities where it is most conspicuous are in Weathersfield and Grafton.

V. EPIDOTIC GNEISS.

This variety is not abundant in Vermont. It usually contains some hornblende as well as epidote. It is the green variety of epodite that is thus associated, and the gneiss is accordingly tinged slightly with this color. It is found chiefly in the gneiss along Connecticut River.

VI. CALCAREOUS GNEISS.

We cannot say how much of the gneiss contains carbonate of lime. It is generally the case that the layers of gneiss adjoining beds of saccharoid limestone are largely composed of this mineral, but it is not generally supposed that there is much lime in the gneiss elsewhere. Almost by accident we tested a suite of specimens of the gneiss in Mount Holly and Wallingford, upon Section V, and found that nine out of twenty-four specimens were calcareous. In general these specimens were not from the vicinity of beds of limestone. But it is remarkable that so many of them should be calcareous. Whether specimens from other localities would show a large per cent. of the calcareous varieties, remains to be proved. We think it doubtful whether the lime is abundant elsewhere. If lime is abundantly diffused through the gneiss, it is remarkable that it should not have been developed in the form of lime feldspar, as it has been in the Laurentian rocks. The inference has been drawn, that the gneiss of Vermont is not Laurentian because the lime feldspar is wanting. But if the lime should be present in the rock, though in another form, would it not be sufficient to identify the gneiss in different localities, so far as can be done by the aid of their chemical composition? We are in great danger, however, of using chemical and lithological characters in distinguishing strata, as if they were as consequential as organic remains.

VII. TALCOSE GNEISS.

This is composed of feldspar, quartz, and the so-called talc of the talcose schist of Vermont. Or it may be gneiss with talcky seams. Examples of it may be found in the State Cabinet, from North Londonderry.

VIII. FELDSPAR AND QUARTZ.

A large part of the gneiss is deficient in mica, and is, therefore, composed of feldspar and quartz. It occurs in thick-bedded masses, semi-granitic; or it may occur in thin layers, and be quite fine grained.

This variety is found in almost every part of the gneiss, but we would specify the gneiss of Cavendish, upon Section V, as a locality where beds of this variety are particularly numerous. The thick-bedded masses are more common in the gneiss found along Connecticut River.

IX. HORNBLENDE SCHIST.

This rock is described separately; but it must be reckoned as an associated rock, because not only are many of the ranges to be described interstratified with gneiss, but it is very common to find thousands of layers of hornblende schist in all well developed gneiss. There is every variety, from hornblendic gneiss to hornblende schist. The hornblende rock is sometimes deficient in quartz, as in the numerous beds of hornblende at Mount Holly. It is there nearly pure hornblende, and, on account of its fine grained structure, it is with difficulty distinguished from trap rock.

X. BEDS OF QUARTZ ROCK.

Quartz rock is not very common in thick beds, but the number of strata of quartz in the gneiss is legion. They are generally so thin that no notice is taken of them, but they are classed directly as gneiss. We should not pass them by, nevertheless, in the attempt to describe faithfully the characters of the gneiss as a formation.

XI. XII. BEDS OF CALCAREOUS AND MAGNESIAN ROCKS.

The numerous beds of limestone, dolomite, steatite, and serpen'ne, need mention at this point only to remind us that they form parts of this formation, although, on account of their theoretical and economical importance, they are described separately.

XIII. TALCOSE AND CHLORITE SCHISTS.

It may seem strange that talcose and chlorite schists should be associated with gneiss. They are not very abundant, however. Talcose schist always occurs in connection with the beds of steatite, serpentine, and sometimes dolomite. Both talcose and chlorite schists are interstratified with gneiss at Mount Holly.

XIV. MICA SCHIST.

So large a belt of mica schist in the gneiss is found in the towns of Cavendish and Chester, that it is designated as such on the map, distinct from the gneiss. This is one of the best characterized beds of mica schist in the State. It resembles lithologically the nobler varieties of the mica schist of the great calciferous mica schist group. Mica schist is also common in the gneiss elsewhere; e. g. in Grafton and Athens, near the two beds of steatite.

XV. EURITE.

Eurite is an unstratified rock, and is a fine grained aggregate of quartz and feldspar; no mica is present unless it be in minute invisible flakes. The only locality of this rock we have found in the State is in the northeast part of Londonderry, No. $\frac{4}{80}$ in the Cabinet. The gneiss adjoining runs N. 15° E., and dips 60° E. The eurite formed a sort of bed three feet wide, whose position is very nearly that of the gneiss. It is very near a large mass of syenite, and veins of epidotic granite and syenite are abundant in the vicinity.

Other unstratified rocks occur in the gneiss. The trap dikes and overlying masses of trap are the most prominent next to granite. The largest mass of granite is in Stamford. Others are in Sunderland, Ripton, and at Cuttingsville. The largest amount of trap may be seen at Mount Holly and Shrewsbury, along the Rutland and Burlington Railroad.

STRIKE AND DIP OF THE STRATA.

The following observations have been made of the strike and dip of the strata of gneiss, arranged according to their occurrence in the different terrains:

GNEISS ALONG CONNECTICUT RIVER.

Locality.	*Strike.*	*Dip.*	*Observer.*
South Vernon,		15° W.,	C. H. H.
Vernon, south part,	N. 45° W.,	90°, (?)	C. H. H.
Vernon, south part,	N. 55° W.,	55° S.W.,	C. H. H.
Northfield, Mass.,	N. 45° E.,	30° S.E.,	C. H. H.
Vernon,	N. and S.,	55° E.,	E. H.
Vernon,		70° E.,	C. H. H.
Bellows Falls (Connecticut River),	N. 50° W.,	26° N.E.,	C. H. H.
Guildhall,		25° E., (?)	C. H. H.

GNEISS BETWEEN THE CALCIFEROUS MICA SCHIST AND THE TALCOSE SCHIST.

Marlboro, village,	N. 20° E.,	75° E., 80° E., & 55° E.,	C. H. H.
Marlboro, Union House,	N. 34° E.,	55° E.,	C. H. H.
Marlboro, west of do.,	N. 30° E.,	30° E.,	C. H. H.
Newfane, west part,	N. 45° W.,	40° S.W.,	C. H. H.
Newfane, west part,	N. 60° E.,	50° S.W.,	C. H. H.
Williamsville, in two places,	N. 45° E.,	65° S.E.,	C. H. H.
Williamsville,	N. 30° E.,	65° S.E.,	C. H. H.
Newfane, northwest part,	East of north,	65° N.W.,	C. H. H.
Newfane, northwest part,	N. 40° E.,	70° W.,	C. H. H.
Newfane, near Fayetteville,	East of north,	15° E.,	C. H. H.
Fayetteville,	East of north,	10° E.,	C. H. H.
Townshend, south part,	N. 40° E.,	90°,	C. B. A.
Townshend, south part,	E. and W.,	10° N.,	C. B. A.
Townshend, center,	N. 45° E.,	50° S.E.,	C. H. H.
Townshend, Bemis' Soapstone,	N. 40° E.,	50° N.W.,	C. H. H.
Townshend, middle part,	N. 40° E.,	80° N.W.,	C. H. H. and C. B. A.
Townshend, northwest part,	N. 25° E.,	60° W.,	C. H. H.
Townshend, north part,	N. 40° E.,	45° W.,	C. B. A.
Athens, Holbrook's limestone,	N. 45° E.,	48° N.W.,	C. H. H.
Athens, north part,	N. 80° E.,	53° N.,	C. H. H.
Grafton, south line at steatite,	N. 70° E.,	36° N.,	C. H. H. and A. D. H.
Grafton, steatite beds,	N. 50° E.,	26° N.W.,	C. H. H.
Grafton, east of steatite,	N. 10° E.,	42° E.,	C. H. H.
Grafton, southeast corner,	East of north,	Dip east,	C. H. H.
Grafton, near Houghtonville,	East of north,	25°–30° W.,	C. H. H.
Grafton, center,	East of north,	75° W.,	C. H. H.
Grafton, near Eagle Mills,	N. 25° E.,	55° W.,	C. H. H.
Grafton, near steatite,	N. 50° E.,	50° N.W.,	C. B. A.
Grafton, west part,	N. and S.,	45° W.,	C. B. A.
Grafton, southwest part,	N. 20° E.,	20° W.,	C. B. A.
Cambridgeport,	N. 20° E.,	56° E.,	C. H. H.
Grafton, Chester line,	N. and S.,	50° W.,	C. B. A.
Windham, Pierce's steatite,	N. 50° E.,	50° S.E.,	C. H. H. and A. D. H.
Windham, Pierce's steatite,	N. 20° E.,	57° E.,	C. H. H. and A. D. H.
Windham, Pierce's steatite,	N. and S.,	45° E.,	C. H. H. and A. D. H.

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Locality.	*Strike.*	*Dip.*	*Observer.*
Windham, Pierce's steatite,	N. 5° W.,	80° E.,	C. H. H. and A. D. H.
Windham, Pierce's steatite,	N. 45° W.,	50° S.E.,	C. H. H. and A. D. H.
Windham, southeast part,	N. and S.,	60° E.,	A. D. H.
Windham, southeast part,	N. and S.,	40° E.,	C. H. H.
Rockingham, Bartonsville,	N. 20° E.,	52° E.,	C. H. H.
Rockingham, northwest part,	N. 10° E.,	66° W. (?),	C. B. A.
Chester, south part,	East of north,	25° S.E.,	C. H. H.
Chester, north part,	N. 8° E.,	50° W.,	C. B. A. and C. H. H.
Chester, northeast part,	East of north,	40°–10° W.,	C. H. H.
Baltimore,			
Springfield, northwest part,		Horizontal,	C. H. H.
Weathersfield, from Perkinsville to Downer's Tav.,	N. 10° W.,	20° E.,	C. H. H.
Weathersfield, northwest part,		60° W.,	C. H. H.
Weathersfield, Greenbush (east),		16° E.,	C. H. H.
Weathersfield, west of Downer's,		7° W.,	C. H. H.
Weathersfield, west part,		14° E.,	C. H. H.
Weathersfield, near Perkinsville,	N. 15° W.,	40° E.,	C. B. A.
Weathersfield, J. A. Strow's,	N. 10° W.,	40° E.,	C. H. H. and A. D. H.
Weathersfield, one-eighth mile east of do.,	N. 10° W.,	50° E.,	C. H. H. and A. D. H.
Weathersfield, Mount Ascutney,	N. 10° W.,	58° E.,	C. H. H. and A. D. H.
Weathersfield, Mount Ascutney,	N. 30° W., (disturbed)	44° N.E.,	C. H. H. and A. D. H.
Weathersfield, west of Strow's,	N. 20° E.,	63° E.,	C. H. H.
Weathersfield, Gulf,	N. 10° W.,	55° E.,	C. H. H.
Weathersfield, Amsden's Mill (lime bed),	N. 45° E.,	52° N.W.,	C. H. H.
Weathersfield, Amsden's Mill,	N. 30° E.,	65° N.W.,	C. H. H.
Weathersfield, Craigue's limestone,	N. 60° E.,	16° N.E.,	C. H. H.
West Windsor, near Felchville,	N. 20° E.,	10° E.,	C. H. H.
Cavendish, east part,	East of north,	15° W.,	C. H. H.
Cavendish, "New City,"	N. 30° E.,	20° W. and 12° W.,	C. H. H.
Cavendish, east part,	N. 20° E.,	20° W.,	C. H. H.
Cavendish, a mile from village,	N. and S.,	15° W.,	C. H. H.
Cavendish, dolomite bed,	N. 10° E.,	30° W.,	C. B. A.
Cavendish, old river bed,	N. 20° E.,	32° W.,	C. H. H.
Cavendish, village, west end of railroad cut,		45° W.,	C. H. H.
Cavendish, village,	East of north,	From 45° W. to 90°,	C. H. H.
Cavendish, west part of village,	N. 5° E.,	60° E.,	C. H. H.
Cavendish, a fourth mile west of village,	N. 20° E.,	70° W.,	C. H. H.
Cavendish, west of village,	N. 17° W.,	80° W.,	C. H. H.
Cavendish, east of Gov. Fletcher's house,	N. 18° E.,	77° W.,	C. H. H.
Proctorsville, near Gov. Fletcher's,	N. 15° E.,	90°,	C. H. H.
Proctorsville,	N. 5° E.,	58° E.,	C. H. H.
Cavendish, south of village,	N. 10° E.,	50° W.,	C. B. A.
Cavendish, south part,	N. 10° E.,	60° W.,	C. B. A.
Cavendish, south of Proctorsville,	N. 15° E.,	70° E.,	C. B. A.
Cavendish, northwest part,	N. 10° E.,	60° E.,	C. H. H.
Reading, near Felchville,	N. 55° W.,	45° N.W.,	C. B. A.
Reading, west part,	N. 10° E.,	60° E.,	C. H. H.
Woodstock, west line,	N. 20° E.,	30° E.,	C. H. H. and A. D. H.
Barnard, south part,	N. 20° E.,	20° E.,	C. B. A.

Mean strike thus far N. 26° E. — 10° = N. 16° E. of true meridian.

GNEISS ALONG THE GREEN MOUNTAIN RANGE.

Locality.	*Strike.*	*Dip.*	*Observer.*
Whitingham, Jacksonville,	N. 30° E.,	40° E.,	C. H. H.
Whitingham, east of center,	N. 35° E.,	10° E.,	C. H. H. and A. D. H.
Whitingham, center,		Horizontal,	C. H. H.
Whitingham, west of center,	N. 10° W.,	40° W.,	C. H. H.
Whitingham, west of center,	N. 15° W.,	40° W.,	C. H. H.
Whitingham, near Kentfield's Kiln,	N. 10° W.,	25° W.,	C. H. H.
Whitingham, west part,	N. 65° E.,	18° N.W.,	C. B. A.
Readsboro Hollow,		30° W.,	C. H. H.
Readsboro, west of the Hollow,		30° E.,	C. H. H.
Readsboro Falls,	N. 10° W.,	45° E.,	C. H. H.
Readsboro, southwest part,	N. and S.,	25° W.,	C. B. A.
Readsboro, northeast corner,		80° E.,	C. H. H.
Woodford, southeast corner,	N. 10° E.,	75° W.,	C. H. H.
Hartwellville,		60° E.,	C. H. H.
Woodford, west part (?),	N. 55° E.,	78° W.,	C. H. H.
Stamford, northeast part,	N. 20° E.,	40° E.,	C. H. H.
Stamford, village,	N. 45° E.,	30° S.E.,	C. H. H.
Stamford, north of village,		10° E.,	C. H. H.
Searsburgh, south part,	N. 70° W.,	80° N.,	C. H. H.
Searsburgh, middle part,	N. 60° E.,	75° S.E.,	C. H. H.
Searsburgh, middle part,	N. 50° E.,	50° S.E.,	C. H. H.
Searsburgh, middle part,	East of north,	37° E.,	C. H. H.
Searsburgh, middle part,	East of north,	Nearly perpendicular,	C. H. H.
Searsburgh, north line,	N. 30° E.,	25° W.,	C. H. H.
Searsburgh, north line,	N. 30° E.,	35°–40° W.,	C. H. H.
Searsburgh, east part,	N. 31° E.,	40° E.,	C. H. H.
Wilmington, south part,	East of north,	20° E. and 20° S.E.,	C. H. H.
Wilmington, south of center,		5° S.E.,	C. H. H.
Wilmington, east of center,	N. 75° W.,	20° N.,	C. H. H.
Wilmington, middle part,	N. and S.,	33° E.,	C. B. A.
Wilmington, east part,	N. 30° E.,	55° W.,	C. H. H.
Somerset, iron mine,	East of north,	10° E.,	C. H. H.
Somerset, east part,	N. and S.,	25° E.,	C. H. H.
Somerset, middle part,		15° E.,	C. H. H.
Somerset, Texas,	N. 30° E.,	75° E.,	C. H. H.
Somerset, iron mine,	N. and S.,	20°–90° E.,	E. H.
Somerset, west part,	East of north,	70° E.,	C. H. H.
West Wardsboro,	N. 40° E.,	45° S.E.,	C. H. H.
West Wardsboro,	N. 70° E.,	35° S.E.,	A. D. H.
Wardsboro, near North Wardsboro,	N. 40° E.,	27° S.E.,	C. H. H.
North Wardsboro,		25° E. and horizontal,	C. H. H.
Wardsboro, northwest corner,	N. 80° E.,	40° S.,	C. H. H.
Jamaica, southwest part,	N. 80° E.,	40° S.,	C. H. H.
Jamaica, center,	N. 20° W.,	50° E.,	C. H. H.
Jamaica, middle part,	N. 30° E.,	East,	C. H. H.
Jamaica, northwest part,		Horizontal,	C. H. H.
Stratton, pot-hole, southeast part,	East of north,	35° E.,	C. H. H.
Stratton, Lyman's limestone,	N. 60° E.,	45° S.E.,	C. H. H.
Stratton, west part,	N. 10° E.,	55° E.,	C. H. H.
Sunderland, Kelly's Hotel,	N. 70° E.,	Nearly 90° E.,	C. H. H.

Locality.	*Strike.*	*Dip.*	*Observer.*
Sunderland, west part,	N. 70° E.,	56° S.E.,	C. H. H.
Sunderland, west part,	N. 45° E.,	60° S.E.,	C. H. H.
Sunderland, west part,	N. 80° E.,	56° S.,	C. H. H.
Sunderland, junction with quartz,		70° E. and 90°,	E. H. and C. H. H.
Winhall, Bondville,		25° E.,	C. H. H.
Winhall, north part,	N. 80° W.,	70°–75° S.,	C. H. H.
Winhall, north part,		Dip west,	C. H. H.
Londonderry, south part,	N. 75° W.,	45° N.,	C. B. A.
Londonderry, east part,	N. 15° E.,	60° E.,	C. H. H.
Londonderry, north part,	N. 10° E.,	40° E.,	C. H. H.
North Londonderry,	N. 10° E.,	8° E.,	C. H. H.
North Londonderry, west of village,		Horizontal,	C. H. H. and A. D. H.
Landgrove,		25° W.,	C. H. H.
Peru, west part,	N. 30° E.,	38° W.,	C. H. H. and E. H., jr.
Mt. Holly, east line,	N. 20° E.,	60° E.,	A. D. H.
Mt. Holly, railroad cut,	N. 20° E.,	70° E.,	A. D. H.
Mt. Holly, east of middle,	N. 75° W.,	85° S.W.,	E. H., jr.
Mt. Holly, church,	N. 12° E.,		E. H., jr.
Mt. Holly, east part,	N. and S.,	50° W.,	C. B. A.
Mt. Holly, north part,	E. and W.,	90°,	C. B. A.
Mt. Holly, west of church,	N. 85°–N. 80° E.,		E. H., jr.
Mt. Holly, northwest part,	N. and S.,	Dip east,	C. B. A.
Mt. Holly, northwest part,	N. 70° E.,	75° N.W.,	C. B. A.
Wallingford, east part,	N. 65° E.,	20° S.E.,	E. H., jr.
Wallingford, east part,	N. 45° E.,	60° S.E.,	E. H., jr.
Wallingford, east part,	N. 30° E.,	70° E. to 90°,	C. H. H. and E. H., jr.
Wallingford, east part,		80° W. to 80° E.,	A. D. H.
Wallingford, east part,	N. 70° E.,	68° E.,	E. H., jr.
Shrewsbury, Cuttingsville,	N. 70° E.,	30° S.E.,	A. D. H.
Shrewsbury, southwest part,	N. and S.,	85° E.,	C. B. A.
Shrewsbury, south part,	N. and S.,	75° E.,	A. D. H.
Plymouth,			
Mendon, north part,	N. 45° W.,	50° S.W.,	C. B. A.
Mendon, northeast part,	N. 10° E.,	25° E.,	C. H. H.
Mendon, east line,	N. 20°–30° E.,	15°–20° E.,	C. H. H.
Sherburne, west part,	N. and S.,	50° E.,	E. H., jr.
Sherburne, west part,	N. 10° W.,	70° E.,	C. B. A.
South Chittenden,	N. 10° E.,	45° E.,	C. H. H.
Chittenden, east part,	N. 10° W.,	54° E.,	C. B. A.
Chittenden, west part,	N. 25° E.,	35° E.,	C. H. H.
Goshen, east part,		50° E.,	C. H. H.
Hancock, Flint's tavern,	N. 20° W.,	Generally 70° E.,	C. H. H. and A. D. H.
Hancock, Flint's tavern,	N. 20° W.,	70° W.,	C. H. H.
Ripton, east part,	N. 10° E.,	69° E.,	C. H. H. and A. D. H.
Duxbury, Camel's Hump, top,	About N. and S.,	20°–39° W.,	C. H. H.
Duxbury, Camel's Hump, part way up,		8° E.,	C. H. H.
Duxbury, valley east of Camel's Hump,		50° E.,	C. H. H.
Waterbury, west of village,	N. 8° E.,	60° E.,	C. H. H. and A. D. H.
Waterbury, west part,	N. 20° E.,	55° E.,	C. H. H. and A. D. H.
West Waterbury, at railroad bridge,	N. 10° W.,	67° E.,	C. H. H.
West Waterbury, railroad cut,		35°–40° E.,	C. H. H.
Waterbury, west part,	N. and S.,	75° E.,	C. B. A.

Locality.	*Strike.*	*Dip.*	*Observer.*
Waterbury, northwest part on Waterbury River,	N. 10° E.,	55° E.,	Z. T.
Waterbury, half mile up Cotton Brook,	N. 14° W.,	54° E.,	Z. T.
Waterbury, three-fourths mile, do.,	N. 4° E.,	64° E.,	Z. T.
Waterbury, one mile, do.,	N. 11° E.,	44° E.,	Z. T.
Waterbury, one and a half miles, do.,	N. 24° E.,	45° E.,	Z. T.
Bolton, east part on Winooski River,	East of north,	45° E.,	C. H. H.
Bolton, do., further west,		Horizontal,	C. H. H.
Bolton, Barber's house,	N. 10° E.,	Dip increases suddenly from 0°–60° W.,	C. H. H.
Bolton, west part on Winooski River,	N. 30° E.,	80° W.,	C. H. H. and A. D. H.
Bolton, northeast part,	N. 10° E.,	45° E.,	C. B. A.
Bolton, Colton's mill,	N. 15° E.,	65° W.,	Z. T.
Bolton, half mile east of Colton's,	N. 4° E.,	80° W.,	Z. T.
Bolton, half mile north of river on road to Colton's,	N. 9° E.,		Z. T.
Bolton, half mile below Smith's P. O.,	N. 20° E.,	64° W.,	Z. T.
Stow, on Waterbury River, near south line,	N. 10° E.,	46° E.,	Z. T.
Stow, two miles southwest from center,	N. 20° E.,	64° E.,	Z. T.
Stow, near center,	N. 25° E.,	75° E.,	Z. T.
Underhill, foot of Mansfield Mountain,		75° W.,	Z. T.
Underhill, west side of Mansfield Mountain,		45° W.,	A. D. H.
Underhill, west foot of Mansfield Mt., N. of previous obs.,	N. 45° E.,	19° N.W.,	C. H. H.
Underhill, west side of Mansfield Mountain,		15°–20° W.,	C. H. H.
Underhill, summit Mansfield Mountain,		0°–10° S.E.,	C. H. H.
Underhill, summit Mansfield Mountain,		Contorted, but nearly 0°,	A. D. H.
Stow, east side Mansfield Mountain,		55° E.,	A. D. H.
Cambridge Borough,		About 90°,	C. H. H.
Cambridge, east of Borough,	N. 30° E.,	83° W.,	S. R. H.
Cambridge, a mile west of center,	N. 32° E.,	About 90°,	S. R. H.
Cambridge, east of center,	N. 20° E.,	63° W.,	C. H. H.
Cambridge, two miles east of center,	N. 20° E.,	65° W.,	S. R. H.
Cambridge, east part,	N. 20° E.,	30° W.,	C. H. H.
Cambridge, east part,	N. 40° E.,	4° W.,	S. R. H.
Johnson, west line,	East of north,	10° E.,	C. H. H.
Johnson, west part (bridge),	East of north,	30° E.,	C. H. H.
Johnson, west part,	N. 25° E.,	65° E.,	S. R. H.
Johnson, half a mile west of village,	N. 20° E.,	Variable,	S. R. H.
Johnson, west part,	N. 10° W.,	60° E.,	Z. T.
Johnson, Bridge Falls,	N. 10° E.,	54° E.,	Z. T.
Waterville, south part,	N. 15° E.,	75° W.,	C. B. A.
Waterville, mills,		25° S.W.,	Z. T.
Hazen's Notch,	N. 80° E.,	80° S.,	S. R. H.
Montgomery, half mile west of center,	N. 70° E.,	40° S.E.,	S. R. H.
Montgomery, east part,	N. 70° E.,	47° S.E.,	C. B. A.
Jay Peak, Summit,	N. 10° E.,	75° W.,	C. B. A.
Jay, east part,	N. and S.,	80° E.,	C. B. A.
Richford, east part,	N. 30° E.,	38° W.,	C. H. H.
Sutton, C. E.,	N. 80° E.,	35° S.,	C. H. H.
Richford, north of Jay Peak,	N. 50° E.,	75° W.,	S. R. H.

Mean of Green Mountain gneiss, N. 30° E. — 10° = N. 20° E. Mean of all the gneiss, N. 18° E. Strike of the formation, N. 10° E.

These observations, so far as they belong to the various sections, may be classified as follows:

	East Range.	*Middle Range.*	*West Range.*
Section in Mass.,	Anticlinal,	Wanting,	All dip east.
Section I,	All dip east,	Anticlinal,	Anticlinal and synclinal.
Section II,	Anticlinal,	Synclinal (?),	Four axes,
Section III,	Wanting,	Anticlinal,	All dip east.
Section IV,	All dip east,	Anticlinal and synclinal,	Three axes.
Section V,	Anticlinal,	Two axes,	Anticlinal.
Section VI,	Wanting,	Dip east,	All dip east.
Section VII,	Wanting,	Wanting,	All dip east.
Section VIII,	Wanting,	Wanting,	All dip east.
Section IX,	Wanting,	Wanting,	Anticlinal.
Section X,	Wanting,	Wanting,	Anticlinal.
Section Xa,	Wanting,	Wanting,	Anticlinal.
Section XI,	Wanting,	Wanting,	Anticlinal.
Section XII,	Wanting,	Wanting,	All dip west.
Section XIII,	Wanting,	Wanting,	All dip east.

It should be observed, in drawing inferences from this classification, that in some cases in the east range, the observation relates not to the range along Connecticut River, but to a reappearance of the middle range, brought up by an anticlinal, and exhibited by erosion. The general inclination of the Connecticut River range is easterly.

The western range is the only one which is found upon all the sections. Although the strata all dip east in several instances, it is plain that the range has a fundamental anticlinal structure. It has been brought to view by the plication of the Green Mountains. Those strata which dip east are probably inverted anticlinals. Two views may be entertained respecting the middle range: either it is a repetition of the western range, or a highly metamorphosed portion of the calciferous mica schist.

Range, Extent and Thickness.

There may be said to be three ranges of gneiss in Vermont—the Green Mountain range, the middle range and the Connecticut River range. The latter is developed in Vermont in only two places, as the clay slate has generally filled out the whole of the State nearest to the river, so that the gneiss is mostly to be found in New Hampshire. The northern extremity of the middle range is divided into two parts or prongs. The Green Mountain range is simple in its form throughout, being very wide at the south line of the State and tapering to a point in Richford.

GREEN MOUNTAIN RANGE.

This range is supposed to be the continuation of the gneiss and mica schist of the Hoosac Mountain range and adjacent rocks in Massachusetts. One might be disposed to think, upon placing the Vermont and Massachusetts maps side by side, that one of the maps must be erroneous. Such should notice two things: 1. The mica schist of Hoosac Mountain and the gneiss of the Green Mountains belong to the same formation, and the

Massachusetts stratum of mica schist becomes gneiss extremely near the State line, by the addition of a little feldspar. It is a case of the metrmorphism of one rock into another. 2. The examination of the rocks of the two States has brought to light what would never have been discovered in either State by itself, viz: that there is a narrowing of the formations very near the State line. Both the gneiss formation and the talcose schist curve to the westward; so that in Massachusetts the mica schist and gneiss are narrower than in Vermont. The beginning of this bend in the strata may be seen upon our geological map, but it cannot be appreciated except upon a map of the two States conjoined, or upon a geological map of New England.

The eastern part of this range as it first appears in Vermont, is very distinct gneiss, and was mentioned as such in the Geological Reports of Massachusetts. It lies much to the east of the Green Mountains, in the towns of Wilmington, Readsboro, and Whitingham. That which forms the axis of the Green Mountains, in the southeast part of Stamford, is scarcely distinguishable from mica schist. The eastern limit of the gneiss in the first tier of towns is at Jacksonville, the western is half a mile west of the village of Stamford, where it loses itself in granite. In the village of Stamford, and at Hartwellville, the gneiss almost passes into quartz rock, and the same belt of rock continues to the north part of Searsburgh. In Whitingham and Readsboro there is a large amount of dolomite and saccharoid limestone present in the gneiss in the form of beds. The gneiss west of Deerfield River in Readsboro is rather peculiar. It is a very coarse, greenish, massive rock, sometimes containing multitudes of garnets, and blotches of what resembles clay slate. A belt of it has been traced more than a mile in width, from Readsboro to West Wardsboro. Most of the course of Deerfield River in Vermont lies in the trough of a synclinal. Hence the strata of gneiss in a part of their course, as in Wilmington, are nearly horizontal.

The gneiss upon Section II, in the second tier of towns north of the State line, is better characterized than upon Section I. The west part of the gneiss, in Woodford, Glastenbury, Somerset, Stratton, Sunderland, Winhall, etc., is mostly covered by drift, so that its characters are but imperfectly known, and its position is uncertain. In the north part of Readsboro the feldspar is abundant, and the strata run nearly east and west, and stand upon their edges. The structure of the gneiss in Woodford may be surmised by examining the rocks upon Deerfield River, in Searsburgh and Somerset. Some of it is deficient in mica, but feldspar is everywhere abundant, and there are two or three axes, which probably continue into Woodford. Besides the drift, a more serious obstacle to the acquisition of knowledge of the character and position of the gneiss in the towns specified above, exists in the absence of roads, and the scarcity of inhabitants. We have not had, during our explorations, any facilities for the examination of a wilderness.

In the west part of Wardsboro the gneiss is rather obscure, but in a large number of towns to the north, in fact everywhere south of Mount Holly, the gneiss is well characterized. In Jamaica it superabounds in feldspar, and near the village becomes granitic. Along the route of Section V. in Mount Holly and Wallingford, the range is a little more than half its width at the State line. Upon the east part of this section the gneiss is unusually obscure, and has been mistaken by some for talcoid rocks. The west side of the anticlinal displays its gneissoid character more perfectly, as well as the association with it of numerous beds of limestone and hornblende schist. At Cuttingsville there is a large mass of granite in the gneiss. The granite has a peculiar character, and needs a chemical examination. Some of the specimens effervesce with acids, showing the presence in it of a carbonate. There is scarcely any mica in it, and the feldspar predominates at the expense of the quartz. It tarnishes much upon exposure. In a gorge two miles south of Cuttingsville the gneiss is less distinct. In Shrewsbury, east and southeast of Cuttingsville, the gneiss is syenitic.

The pyrites at Cuttingsville apparently is in a bed, being interstratified with the associated rocks. Beneath the pyrites there is a bed of hornblendic gneiss twenty feet thick. The rock capping the bed is an impure limestone, containing concretions of calcite resembling fossils. There is a hornblende dike at the west end of the bed, lying between the ore and the limestone. This dike runs with the ore, and rests upon it over a distance of five rods. The whole length of the bed of pyrites is one-fourth of a mile. There seems to be an anticlinal axis in the middle of the bed. The dip of the adjacent rock varies from horizontal to perpendicular.

The single anticlinal shows itself in the section across Mount Holly, and is illustrated both in Section V, Plate XVI, and Fig. 18. The mountain at Mount Holly is lower than at any point in the State south of Winooski River. The strata upon the west side of this anticlinal are often perpendicular, and may even dip east at some localities. Near Mount Holly station there may be seen subordinate curves in the strata, which will illustrate the character of an inverted anticlinal axis. Near the east line of Mount Holly, on the road to Plymouth, the strata dip about 50° E.

Most of the gneiss in Mendon is concealed by drift, as also in Sherburne upon the route of Section VI. The top of Pico Peak is made up of rather obscure gneiss, with a small easterly dip. It is difficult to learn much about the position of the gneiss upon this mountain, because the ledges are almost entirely concealed from view. The bed of azoic limestone in the north part of Mendon is remarkably large for a bed in gneiss. The greater part of Chittenden is made up of this range. The only ledges we could find were at South Chittenden, and along the west border of the formation north of this village.— The gneiss here contains many pebbles of feldspar, and of other rocks also appearing porphyritic. It is distinctly mica schist in a gulf north of South Chittenden. The gneiss forms very high mountains in the east part of Chittenden, which we have never explored.

The belt of gneiss rapidly narrows in Chittenden, and at Goshen it is narrower than at any other point south of Hazen's Notch. This narrowing of the gneiss seems to be connected with the topography of the northeast part of Chittenden and Pittsfield. Most of the rock of this belt in Goshen is gneissoid rather than true gneiss. It occupies the lower part of the high mountains, Mt. Horrid and others being capped by talcose schist. It is much wider in Hancock and Ripton, and the whole mountain range here is composed of gneiss, without any cap of talcose schist. There are traces of a westerly dip near the top of the mountain, on the west side of Flint's tavern. From Hancock village to Ripton village the rock is gneissoid.

We have not examined the character of the gneiss of the Green Mountains between Hancock and the top of Camel's Hump, but suppose it to be the peculiarly characterized rock over this area that it is generally north of Goshen.

Camel's Hump is an anticlinal of gneiss, or rather it is the west side of such an axis, the east and central parts having been eroded. The rock on top of the mountain is gneissoid, and dips to the west. The character of the gneiss is better seen in the valley of the Winooski River, between Waterbury and Jonesville than upon the high land. The ledges are very numerous there, and more of the rock is exhibited here than upon any other section in the State, unless it be along the La Moille River, where the erosion is similar.— It is curious how easily the axis of the gneiss in Bolton can be overlooked. No record has been preserved by Prof. Adams or any of his assistants. On the contrary they have left sections showing perpendicular strata all the way from Jonesville to Waterbury.— The exact locality where the central horizontal strata of the anticlinal show themselves is to the west of J. Whitcomb's house in Bolton, exactly on the line connecting the top of Camel's Hump and Mansfield Mountain. This we did not discover till our examination of this section. Much of the gneiss along the Winooski River resembles sandstone—the crystals of feldspar being rounded like large grains of sand.

The axis of the gneiss on La Moille River is not far from the town line of Cambridge and Johnson. The amount of feldspar in the gneissoid rocks along this river, and in the whole belt north of this point is small. We have not examined any point in the gneiss north of La Moille river ourselves, and no anticlinal north of this point has been reported by any other person. The strata in Johnson and Cambridge are full of minor irregularities like much of the gneiss along this Green Mountain axis. The rock at Hazen's Notch proves to be gneiss, associated with a little quartz rock. The most northern locality of gneissoid rock represented upon the map is in the east part of Richford. Prof. Adams described the rock upon Jay Peak as talcose schist. It seems to form the continuation of the axis of Mansfield Mountain and Camel's Hump, and may possibly be the same rock in a disguised condition. We certainly found a gneissoid ledge north of Jay Peak in Canada upon the line of strike, and the Reports of the Canada Survey speak of the continuation of the axis of the Green Mountains as being composed of gneiss.

THE MIDDLE RANGE OF GNEISS.

This range extends from Halifax to the Otta Quechee River in Hartford. It is not as extensive as the Green Mountain range, but the average character of the rock is more distinctively gneissic. We have not traced the gneiss as far as the south line of the State, yet suspect it may extend into Massachusetts. It passes insensibly into the mica schist to its eastward. Upon Section II, in Marlboro, this gneiss is first seen in good development. In the east part of the range in Marlboro, hornblende schist and hornblendic gneiss prevail. In the village and west of the village the hornblende is not as abundant, yet the whole of this section through the gneiss may be characterized by the presence of an immense amount of the mineral hornblende. One cannot ask for better characterized gneiss, than may be found upon this range in Marlboro.

In Newfane this range of gneiss is anticlinal, and is gradually increasing in width.— The anticlinal structure is displayed through the whole town. It is immediately overlaid by hornblende schist, like the gneiss in Shelburne, Mass., and in Guilford and Brattleboro, Vt. It is, however, not in their line of strike, though it may be a repetition of the same belt of rock. All these gneissic anticlinals underlie the calciferous mica schist. At

Fayetteville there is a vein of concretionary granite in this belt of gneiss. In Townshend, Athens and Grafton, the amount of gneiss covers a wider area, and is still more characteristically developed. There are two axes here, and several beds of dolomite and steatite. Frequently the gneiss is granitic, or nearly destitute of stratification. It has more of the character of mica schist in the northwest part of Grafton. In the west part of Townshend there are numerous small beds of limestone, occuring much like the beds of silicious limestone in the calciferous mica schist. At Houghtonville there is a bed of hornblende schist; also a wide bed of white quartz. Below Eagle Mills in Grafton, there are large veins of granite in the gneiss. In the vicinity the gneiss contains large crystals of flesh-colored feldspar in great abundance. At Bartonsville in Rockingham, there is hornblende schist associated with the gneiss, both rocks being distorted from pressure. In Chester and Springfield the gneiss is wider than at any other part of this belt. In Chester, north of the village there are small beds of limestone associated with the gneiss. A large mass of black syenitic or hornblendic rock, about a mile in diameter, is also found in the vicinity near Whitmore's Mills. As the gneiss is well characterized in Chester, so minerals are unusually abundant in it, as the list of localities in another part of the Report will show. In many parts of Chester the gneiss is quarried, and makes a valuable stone for building. The stratigraphical structure is that of a synclinal and an anticlinal axis, both in Chester and in Cavendish along the route of Section V. But the axes are the more complicated with minor undulations in Cavendish.

A band of very beautiful mica schist extends from Chester to the north part of Cavendish, from Gassett's station in Chester, to the most northern bend in Black River. Much dolomite, also, is associated with the gneiss in Weathersfield and Cavendish, not in small beds alone, but in several large beds. The gneiss at the "gulf" in Weathersfield is somewhat porphyritic in its appearance; west of the gulf the gneiss is granitic. But in all this region the dip of the gneiss is unusually small and full of small undulations. Yet occasionally the position varies very much suddenly. For instance, at the gulf the strike is N. 10° W., which continues nearly to Amsden's Mill; but at the mill itself the strike is N.E. and S.W., and the dip is in the opposite direction. One cannot but feel that there has been a twist in the strata here. The force may have relieved itself by elevating segments of the strata, rather than plicating them as a whole.

The granite of the two Ascutneys seems to have cut across the strata of the calciferous mica schist, quite a distance into the gneiss. We formerly supposed that the gneiss extended further to the east or the south of this protrusion, than on the north. But a subsequent partial examination has satisfied us that the boundaries of the gneiss and mica schist, are in the same line upon both sides of the syenite. Yet there may be a dislocation of very small extent, unobserved by us. We would not venture to affirm or deny it, without a very careful examination. The presumption is now against it. The gneiss is well characterized in Weathersfield and Cavendish. On the westside of Little Ascutney the dip is apparently beneath the mountain, and north of Felchville the dip is only 10° E. South of Felchville it dips 60° E. Much of the gneiss in Cavendish, particularly between the village of Cavendish and the east line, is deficient in feldspar: so much so that Prof. Adams did not distinguish it from the calciferous mica schist. No one would ever mistake the rock between Cavendish and Proctorsville for any thing but gneiss. A careful examination reveals several minor variations of this synclinal axis, as seen in the enlargement of a part of Section V, on Plate XVI.

The calciferous mica schist divides this middle range of gneiss into two parts as far south as Chester. It has been traced only into the north part of the town, but may be found to extend further, by careful examination. It is a very narrow strip south of Proctorsville, occupying the Proctorsville Gulf, which owes its origin probably to the softer nature of the rock. A very narrow belt of gneiss extends from the west part of Chester, through Cavendish (passing through Proctorsville), Reading west part, and the east part of Bridgewater, into Barnard. A large amount of hornblende schist is associated with this belt of gneiss. The other part of the gneiss we have traced into the north part of Reading. Its prolongation to the Otta Quechee River, is given upon the authority of Prof. Adams. He found a deposit of gneiss in Hartford and Hartland, which was isolated from all other rocks. The middle ranges of gneiss he thought extended no further north than Chester. As we have carried the middle range of gneiss to the south line of Hartland, it seems very probable that the two deposits form parts of one great whole, and we have so represented them upon the map. We suppose that this projection of the gneiss to Hartford forms an anticlinal axis, underlying the calciferous mica schist.

EASTERN DEPOSITS OF GNEISS.

There are three patches of gneiss upon or near Connecticut River in Vermont. One of them is of small width, and exposed to view at the surface in Brattleboro and Guildford, but is not of sufficient width to be represented upon the map. Upon the Massachusetts Section (Plate XV), the same range appears as gneiss underlying hornblende schist at Shelburne Falls. It is exposed by erosion. As erosion has not worn away the overlying rocks north of Shelburne, the gneiss is not seen till we arrive in the north part of Guilford. Upon Section I. the same anticlinal will be noticed, but the erosion has not penetrated through the hornblende schist. Upon Section II. the hornblende schist is fully worn through, and towards half a mile's width of subjacent gneiss appears. This gneiss is rather obscure. Part of it is properly a garnetiferous mica schist. This band is not seen again in Vermont, unless it be in a metamorphic condition in the granite of Black Mountain in Dummerston, and the immense mass of granite in Orange, etc. This granite occupies the same stratigraphical relations to the mica schist, as the gneiss of West Brattleboro.

The gneiss in Vernon and at Bellows Falls on Connecticut River, has a different aspect, is stratigraphically higher, and is probably of a different age from the gneiss just described. The first patch of gneiss that we shall mention is not found out of Vernon, in Vermont; but it extends into Massachusetts on the south, and into New Hampshire on the east. At the extreme southeast corner of the town, with the gneiss are associated mica and hornblende schist. (See Fig. 321.) Further northwest the gneiss becomes thick-bedded, compact and jointed; and is scarcely different from granite, or at times from syenite. There is a belt of mica schist running from South Vernon depot into Bernardston, which forms a part of the group. This band of gneiss curves very much in conformity with the bend in Connecticut River, though not precisely. A narrow belt of arenaceous quartz rock skirts it on the west. This band of gneiss is better developed in Massachusetts than in Vermont, although in the former state its peculiarities have not been much investigated — partly because much of it passes beneath the Connecticut River sandstone of mesozoic age.

This band of gneiss leaves Vermont in the north part of Vernon, but reappears in Westminster and Rockingham at Bellows Falls. The granitoid gneiss is well developed at Bellows Falls. Upon the New Hampshire side it forms a high mountain called Kilburne Peak. Its most southern point in Vermont is in the north part of Westminster. The rocks in the gorge at the falls in Connecticut River, from whence the name of the village, afford a better exhibition of the characters of this rock than at any other place in the State. The rock is filled with several systems of joints, so that it is difficult to ascertain the true position of the planes of stratification. Veins of granite are common in the ledges, and the cavities in the gneiss contain beautiful crystals of wavellite and fluor spar. West of Bellows Falls this rock forms a hill, and southwest of the village it has been cut through by Saxton's River. It does not extend a great distance north of Bellows Falls in Vermont. Perhaps an area of two square miles is underlaid by the gneiss in this patch in Vermont. It does not show itself again in the State, in a recognizable form, unless it be the same with the granitic range from Waterford to Maidstone. There are many points of similarity between the two bands of rock.

The thickness of the gneiss in Vermont must be very great. The section across Mount Holly may perhaps give an average of its thickness. About 8,000 feet of strata have been removed there, of which we should estimate about 6,000 to have been of gneiss. Yet as the bottom of the formation may not be reached here, the true thickness may be greater.

Minerals in Gneiss.*

(Those *italicised* are found either in talcose schist or calciferous mica schist, and have already been described.)

Kyanite, Wavellite, Fluor, Alum, *Staurotide*, White Augite, Prehnite, Chiastolite, *Adularia*, *Tourmalin*, *Indicolite* (variety of Tourmalin), *Calcite*, Fibrolite, *Dolomite*, *Micaceous Iron Ore*, *Magnetic Iron*, *Native Gold*, Scolecite, *Zoisite*, *Tremolite*, Stilbite, Pinite, *Pyrites*, Andalusite, *Calcite*, *Actinolite*, *Red Hematite*, *Octahedral Iron*, *Asbestus*, *Orthoclase*, *Chlorite*, *Massive Garnet*, *Steatite*, *Rhomb Spar*, *Serpentine*, *Epidote*, *Staurotide Quartz*, *Galena*, Iolite, *Graphite Anthophyllite*, *Chrysolite* in Dike.

Wavellite. A subphosphate of alumina with a trace of Fluohydric acid. Primary form a right rhombic prism. Usually occurs in hemispherical implanted globules, with radiated structure. Color white, yellow, green and gray. Found in Vermont at Bellows Falls.

Fluor Spar. Primary form, a cube. Chemical composition, fluorine and calcium. Color white, wine-yellow, violet-blue, emerald-green, pistachio-green, sky-blue, rose-red, and common red (rare.) This mineral furnishes some of the most highly colored specimens in the cabinet, and is used in the massive state for making vases and similar ornaments, known as Derbyshire spar. It is found in Vermont at Bellows Falls and Putney, and is in the Collection No. 49 (Presented by A. D. Roe.)

Alum. This occurs as an incrustation, or more properly an efflorescence, upon many rocks. It is a sulphate of alumina, soda, potash, ammonia, magnesia, etc. The primary form is set down as a cube. It has been found in Vermont at Bethel, Colchester, Somerset, Halifax, and Newfane.

White Augite. This is merely a handsome variety of Pyroxene, known sometimes by the name of diopside and white malacolite. It is found in Vermont at Whitingham, and can be seen in the Cabinet under the Nos. 168 and 169.

*By E. Hitchcock, jr.

Prehnite. This mineral belongs to the Trimetric system of Dana, usually being found in right rhombic prisms. These crystals are usually small ones that are implanted on globular or reniform masses, or incrustations. It is a hydrated silicate of alumina, lime and iron. In color it is of some shade of green. In Vermont it occurs at Bellows Falls and Vernon. Its numbers in the Cabinet are from 318 and 321 inclusive.

Chiastolite. A variety of Andalusite, to be described below.

Fibrolite, or *Sillimanite*, is a mineral generally found in long prisms or fibers, though sometimes massive. The primary form is an oblique rhombic prism from 98° to 110°. It is a silicate of alumina resembling kyanite. Color hair-brown or grayish. It has been found at Saxton's River.

Scolecite. Monoclinic, in radiating balls, which are often quite compact at the center. The color is generally white, but sometimes yellowish, blue and red. It is often called a lime mesotype. Its composition is silica, alumina, lime and water. It has been found at Westminster.

Stilbite. A zeolitic mineral in cavities and seams, with radiating structure. Prevalent color white, with shining luster. Primary form right rectangular prism. Composition hydrated silicate of lime and soda. It has been found at Rockingham.

Pinite. See Iolite below.

Andalusite. A flesh-red or pearl-gray mineral, and known as Macle or Chiastolite and Hollow Spar. Its primary form is that of a right rhombic prism, and its chemical composition a silicate of alumina, with a trace of iron. The variety Chiastolite seems to be owing to impure crystals of differing hardness, which are arranged symmetrically about the axis and edges, giving a beautiful variety of figures to the crystals when cut vertically and polished. It has been found at Saxton's River and Bellows Falls.

Iolite or *Pinite* (above), and above twenty other varieties, according to Professor Shepard. It is, in primary form, a rhomboid, and its secondary form is often a hexagonal prism. Its composition is silica, alumina manganese (oxyd), oxyd of magnesia, and oxyd of iron. The color varies from blue, brownish-yellow to yellowish-gray.

Pinite seems to be an altered form of Iolite. This is a dull, greenish-gray, and is nearly opaque. It is also very soft. While the hardness of Iolite is from 7 to 7.5, Pinite is frequently no higher than 3. This also contains soda and potash in addition to the other ingredients. It has been found at Chittenden and Rockingham.

*Geological Position, Origin, and Metamorphism.**

If we were to limit the term gneiss to a foliated rock highly charged with feldspar, Vermont would afford but little of it. The deposit marked as gneiss upon our map, which intercepts the calciferous mica schist, and seems to take its place, from Hartland to the south line of the State, would constitute its largest deposit. But on traversing the Green Mountains, almost through the entire State, we find them in a great measure made up of a schistose rock, much of which we should refer to mica schist or talcose schist. Yet it contains more or less of feldspar, and sometimes passes into distinct gneiss. Professor Adams called it Green Mountain gneiss; and for a time we were inclined to refer it to that variety of mica schist which McCulloch describes as containing some feldspar. But following the rock on the line of strike, and sometimes crosswise, we often find very distinct gneiss; and hence we concluded to call the whole gneiss, where any considerable quantity of feldspar occurs interfoliated. But such a character is quite indefinite, and no two observers would probably fix the limits of such gneiss in the same place. Hence we consider the color denoting gneiss along the Green Mountains as the most unsatisfactory of all those upon the map. Moreover, those layers of the rocks, on both sides of the

*By E. Hitchcock, Senior,

mountain, which all would regard as gneiss, are generally interstratified with other layers of mica or talcose schist and quartz, and the judgment of good observers would differ about the line where the gneiss predominates over the schists; that is, about the limits of the gneiss.

It is quite instructive to take the Geological Map of Massachusetts, as given in Hitchcock's Final Report of 1840, and trace the geology of the Green Mountain range, first across Massachusetts, and then, by our map, through Vermont. On the south line of Massachusetts, almost the whole breadth of the range, not less than twenty miles, is tolerably well characterized gneiss. Yet as we pass northerly on the line of strike along the eastern margin, the gneiss is rapidly succeeded by mica and talcose schists, and the gneiss becomes so pinched up as to form a mere wedge before we get across the State, and it is doubtful whether the mica schist does not absolutely cut off the gneiss ere we reach the north line. We incline to the opinion, however, that a narrow belt of Green Mountain gneiss does extend across the whole State into Vermont. At any rate, as our map shows, as soon as we enter Vermont the gneiss again spreads out over a very wide belt, though in many places we are obliged to judge of the subjacent rock by the detritus above it. On its eastern side the gneiss is well charged with feldspar; but as we go northerly it becomes less so, and the formation diminishes in width, while the talcose schist spreads out wider and wider to the Canada line. Precisely how far north to extend the gneiss has been a point of difficulty, and how wide to make it. Probably what might not inappropriately be called gneiss may be traced even to the Canada line; but we meet with little north of Lowell.

We have expressed the opinion in another place, that gneiss, mica and talcose schist, and even some beds of quartz may be only metamorphic varieties of the same original formation. Their interstratification within the space of a few rods, certainly makes such a supposition probable. And the remarkable changes of these rocks on the line of strike which we have pointed out, strengthens this hypothesis. Indeed, we have guessed that all these rocks have been produced by the metamorphism of conglomerate at Wallingford and Plymouth, and surely it is still easier to conceive a like metamorphism from other formations. The conclusion seems forced upon us, that the particular kind of rock resulting from metamorphism, depended upon the presence or absence of the requisite ingredients in the water that penetrated the rocks. It might have the ingredients necessary to produce mica or talcose schist, yet not those which would form gneiss. We can, indeed, see how clay slate and hornblende schist might be changed into gneiss, and probably some of the Vermont gneiss had such an origin. But we may derive it from almost any rock if we suppose it permeated by water containing in solution any ingredients, requisite to form feldspar, that are wanting in that rock.

We have already made it probable that the calciferous mica schist has been converted into gneiss from Ascutney southward. If so, whatever the age of the schist may be, that of the gneiss is the same. We have also made it probable that the Green Mountain gneiss forms the center of a folded axis, over which the conglomerate, talcose schist, quartz rock and limestone once mantled. If so, and if we are justified in referring the conglomerate to the base of the upper Silurian, the Green Mountain gneiss, certainly where it forms a folded axis, is probably the oldest of the metamorphic rocks in Vermont—

as we might expect this back bone of the State would be. It would at least be as old as the Hudson River group. But on this subject the clue by which we are trying to feel our way is faint and feeble. We think, however, that a little light has broken in upon this darkness, and we have a hope that the problem will one day be satisfactorily solved.

HORNBLENDE SCHIST.

BY C. H. H.

Hornblende predominates in this rock, but its varieties contain feldspar, quartz and mica. When it is pure hornblende its stratification is often indistinct. It does not form a large group or formation by itself, but is generally interstratified with other rocks, as clay slate, mica schist and gneiss. We shall not attempt to describe all the hornblende schist in the State, but simply half a dozen bands of it, which are sufficiently extensive to have a place upon the map.

Lithological Characters.

There are four varieties of hornblende schist in Vermont. They are

1. Hornblende alone.
2. Hornblende and feldspar.
3. Hornblende and quartz.
4. Hornblende, feldspar and quartz.

I. HORNBLENDE ALONE.

This is the rock often denominated *hornblende rock,* in this Report. It is one of the most common of all the varieties, and is by no means confined to the several bands of hornblende schist represented upon the map. It is found associated with gneiss and clay slate, in positions much like dikes, as well as in regular beds. Its structure may be highly crystalline, or nearly homogeneous. In the latter case, the rock appears to be entirely destitute of stratification or foliation. In the former case, it may form thick folia, or very narrow beds, separated by planes much like cleavage planes. This variety reminds one much of clay slate. For a good example of it, we refer to the hill west of the Methodist church, in Marlboro, in the west part of the town.

II. HORNBLENDE AND FELDSPAR.

Generally the hornblende is crystalline, and the feldspar foliated, or granular; but sometimes both ingredients are compact. There is rarely any distinct marks of this rock, except that the whole deposit is in the form of a bed. When the crystals of feldspar are large, and are rather numerous, the rock resembles porphyry, although the strict definition of porphyry—that the basis rock and the crystals should be composed of the same mineral—does not apply to it. But we have in various places spoken of this rock as *porphyritic hornblende,* because the rock so closely resembles true porphyry. The best development of it in the State, is at Williamsville. It occupies an area there of nearly a square mile, lying between the gneiss and calciferous mica schist. Crystals of rutile and ilmenite are found in it, associated with chlorite. Bowlders from this locality are found scattered all over the Connecticut River valley, in Massachusetts.—Another bed of this rock is in the east part of the calciferous mica schist in Norwich. A similar rock of great width is described under talcose schist in Waterford.

III. HORNBLENDE AND QUARTZ.

True hornblende schist is properly a foliated mixture of hornblende and quartz. The hornblende in crystals forms the principal ingredient, however. The quartz is granular. This passes insensibly into the next variety. The rock is slaty; and is sometimes traversed by veins of quartz or granite.

IV. HORNBLENDE, FELDSPAR AND MICA.

This variety approaches gneiss, but it cannot be called gneiss, as the hornblende predominates. The mica is usually in small quantity, and the feldspar and quartz sometimes traverse the rock in numerous minute veins.

STRIKE AND DIP OF THE STRATA.

Our observations upon the jointed and cleavage (?) structure of the gneiss and hornblende schist have been so few, that they need not be mentioned. The different beds described belong properly to different rocks; but as we had separated the observations upon the strike and dip of the hornblende schist into a list by themselves, it was thought best to present them in this form.

As this rock is associated with different rocks (in some cases it being difficult to determine to which of the great groups it belongs), we simply record the different observations without classification, beginning at the south part of the State, and working northwardly.

Locality.	*Strike.*	*Dip.*	*Observer.*
Guilford, west of center,	N. 20° E.,	55° E.,	C. H. H.
South Vernon,		15° W.,	C. H. H.
Bernardston, Mass.,	N. 45° E.,	30° S.E.,	C. H. H.
West Brattleboro,	N. 28° E.,	67° E.,	C. H. H.
West Brattleboro,	N. 28° E.,	15° E.,	C. H. H.
Brattleboro, west part,	East of north,	18° W.,	C. H. H.
Brattleboro, west part,	East of north,	38° W. and 45° W.,	C. H. H.
Marlboro, east part,	N. 8° E.,	73° E.,	C. H. H.
Marlboro, center,	East of north,	80° E.,	C. H. H.
Marlboro, west of center,	N. 20° E.,	75° E. and 55° E.,	C. H. H.
Marlboro, Union House,	N. 34° E.,	55° E.,	C. H. H.
Marlboro, east of Methodist church,		25° E.,	C. H. H.
Marlboro, west of Methodist church,	N. 32° E., average,	30° E., 18° N., 70° W.,	C. H. H.
Marlboro, west part,	N. 32° E.,	15° E.,	C. H. H.
Wilmington, east part,	N. 75° W.,	20° N.,	C. H. H.
West Wardsboro,	N. 40° E.,	45° S.E.,	C. H. H.
North Wardsboro, east of,	N. 20° E.,	20° E.,	C. H. H.
Newfane (Fayetteville),		10° E.,	C. H. H.
Newfane, west part,	N. 10° E.,	50° W.,	C. H. H.
Newfane (Williamsville),	N. 30° E.,	65° E.,	C. H. H.
Marlboro, Bellows' steatite bed,		50° northerly,	C. H. H.
Windham, southeast part,	N. and S.,	60° E.,	A. D. H.
Windham, southeast part, north of do.,	N. and S.,	36° E.,	C. H. H.
Proctorsville, Gulf,	N. 20° E.,	60° W.,	C. H. H.
Proctorsville,	N. 10° E.,	55° E.–75° E.,	C. H. H.
Proctorsville,	East of north,	80° E.,	C. H. H.
Proctorsville,	N. 17° E.,	80° E.,	C. H. H.
Proctorsville, north part,	N. 40° E.,	82° W.,	C. H. H.
Proctorsville, near Gov. Fletcher's house,	N. 15° E.,	90°,	C. H. H.
Cavendish, northwest part,	N. 10° E.,	60° E.,	C. H. H.
Newbury, north of village,	N. 40° E.,	76° W.,	C. H. H.
Charleston,	N. 10° E.,	74° W.,	C. H. H.
Holland,	N. 20° E.,	40° W.,	S. R. H.
Grafton, west part,		25°–30° W.,	C. H. H.
Cambridgeport,	N. 20° E.,	56° E.,	C. H. H.
Rockingham, Bartonsville,	N. 20° E.,	52° E.,	C. H. H.
Mt. Holly, east part,	N. 36° E.,	46° S.E.,	E. H., jr.

This rock is frequently remarkable for the numerous and complicated contortions which its layers exhibit, often rivalling in this respect any other rock in the State. Sometimes these irregularities appear to be increased by the passage of granite veins through the rock. Nos. $\frac{4}{103}$ and $\frac{4}{104}$ in the Cabinet, are specimens of contorted hornblende schist from Peru.

Range, Extent and Thickness.

There are several belts of hornblende schist in Vermont, six of which are represented upon the Geological Map, Plate I. Two of them are in calciferous mica schist, two in gneiss, and two in talcose schist.

A small range in gneiss, which is not represented upon the map, is in Vernon, being the northern prolongation of quite a large band of hornblende schist in Bernardston, Gill and Northfield, Mass. It is found only in the southeast part of the town.

The largest band of hornblende schist is in Brattleboro and Guilford, extending from Massachusetts. It forms an anticlinal axis resting directly upon gneiss. Its relations may be discovered by examining its position upon Sections I. and II, and the Massachusetts Section at Shelburne Falls. It is seen in all these cases to overlie the gneiss, and underlie the mica schist. It more properly belongs to the gneiss, than the mica schist. In Massachusetts some of this belt approaches hornblendic gneiss; in Vermont it is often pure hornblende, an exceedingly tough black rock.

The other range of hornblende schist in the calciferous mica schist group extends from Holland to Greensboro, passing through the towns of Charlestown, Salem, Brownington, Barton and Glover. This range is described by Rev. S. R. Hall as interstratified with mica schist and silicious limestone. It varies in width from a few rods to two or three miles. It probably extends to Cabot.

So much hornblende exists in the gneiss in Marlboro and Newfane, that we represent two bands of hornblende schist in these towns upon the map; one upon the west and the other upon the east side of the formation. The rock is mostly true hornblende schist, but it is interstratified with hornblendic gneiss. The western of these ranges may extend from Halifax to Townshend, and may possibly connect with another range in Windham. It lies west of the porphyritic hornblende at Williamsville; yet it probably belongs to the same belt of rock, upon opposite sides of an anticlinal axis. The same anticlinal appears at Fayetteville. The hornblende schist west of Fayetteville is remarkable slaty, and it is of great width. A large amount of the hornblende schist shows itself between Williamsville and the Newfane bed of steatite and serpentine. Local beds of hornblende schist in the gneiss in the south part of the State are specified in the descriptions of the general sections; and their character may be learned from the nature of the specimens in the State Cabinet illustrating them.

The most southern band of hornblende schist is located in the extreme west part of Marlboro, capping a hill west of the Methodist Church. This is of two kinds—the thick-bedded rock containing beautiful garnets, and the thin-bedded, or slaty variety. The irregularities in the dip of this belt are remarkable, especially upon Section II, to which we refer for the facts. The other band of hornblende schist is in Windham. It lies between the gneiss and talcose schist. Section IV. crosses it. It is developed between Pierce's bed of steatite and Whitman's bed of serpentine, and is about seventy-five rods wide. Its length is unknown to us.

Another band of hornblende schist is in the mica schist of Norwich. Other bands exist doubtless in the northern part of the State, besides the one mentioned, but we have not traced them out carefully enough to represent them by colors. Wherever we have found beds of it on any Section it will be noticed in the descriptions of that Section. The hornblende schist of the Brattleboro and Guilford range is 250 feet thick.

Mineral Contents.

This rock contains very few simple minerals, as it is mostly a mineral by itself. The most beautiful mineral ever found in it is garnet. They are small but very distinct, and of a blood-red color. The best localities are in Marlboro and near Dartmouth College, a short distance over the New Hampshire line. Other minerals found in it, are rutile, ilmenite, chlorite, orthoclase, tourmaline, sphene, epidote, and pyrites.

Geological Position.

Most obviously the hornblende schist of Vermont has the same geological age as the formations in which it occurs. It is therefore of four ages: 1. Age of the middle range of gneiss. 2. Age of the South Vernon gneiss. 3. Age of the talcose schist; and 4. Age of the calciferous mica schist.

Origin and Metamorphism.

We might very properly consider this rock as a variety of gneiss, taking hornblende into its composition; for feldspar is most commonly present. Sometimes, however, it is composed of hornblende, quartz, and mica in folia, and sometimes it is nearly pure hornblende. It is generally associated with gneiss, sometimes interstratified with it, but more usually overlying it on an anticlinal, as at Shelburne Falls, in Massachusetts, and in Guilford, as our sections show. Hence it is somewhat newer than the gneiss.

Dr. McCulloch long ago pointed out examples in which hornblende schist had resulted from the metamorphosis of clay slate. "As far as a single fact can prove such a case," he says, "the origin of hornblende schist from clay slate is completely established by the occurrence, in Shetland, of a mass of the latter substance, alternating with gneiss and approximating to granite. Here those portions which come into contact with the latter become first silicious schist, and ultimately hornblende schist; so that the very same bed which is an interlamination of gneiss and clay slate in one part, is in another the usual alternation of gneiss and hornblende schist." "It would appear that the fusion of clay slate, whether primary or secondary, is, under various circumstances, capable of generating either the common trap rocks or the hornblende schists."

McCulloch here supposes the metamorphism produced by dry heat, and the frequent occurrence of hornblende crystals in lava, would seem to favor such an origin of hornblende. But Bischof has made it quite probable that even in lava the hornblende was not formed at the time of the protrusion of the lava, but subsequently, in the wet way; and the associations of hornblende schist forbid the idea that it was a volcanic product. It must have been formed in the same way as the schists and. gneiss with which it is associated.

MICA SCHIST.

BY E. HITCHCOCK, SENIOR.

The normal description of this rock makes it consist of alternate layers of mica and quartz; but often it passes insensibly into other schists, and the ingredients are much modified. The quartz sometimes disappears, leaving only small flakes of mica and then verges towards, and at length becomes clay slate. On the other hand the laminæ of quartz become thicker and the mica less, until quartz rock is the result. Sometimes it takes other simple minerals into its composition; as for instance talc, when it becomes talcose schist, or hornblende, which at length converts it into hornblende schist, or feldspar, which makes it gneiss. But the most important variety, so far as Vermont is concerned, is where the rock takes into its composition carbonate of lime. It does not simply contain interstratified beds of the lime, but the two ingredients interpenetrate each other; sometimes one predominating and sometimes the other. This we call calciferous mica schist, and it so predominates in the State that we have sometimes doubted whether all the mica schist that exists there was not originally of this description, and subsequently deprived of its lime in some cases by metamorphic action. We shall, however, place one or two bands of pure mica schist upon the map; but the greater part is calciferous mica schist.

Lithological Characters.

The preliminary remarks that have been made will much abbreviate the descriptions which follow.

1. *Mica and Quartz.* The two minerals are interlaminated, and vary in relative quantity.

2. *Arenaceous.* Here the quartz is in the form of a fine, usually gray sand; the mica, however, has a parallel arrangement. This is the variety used for whetstones and firestones. It is sometimes called Whetstone Slate.

3. *Argillo-micaceous.* This is when the rock passes into clay slate, as above described; and often over wide areas it is difficult to say whether the rock should be called mica schist or clay slate.

4. *Plumbaginous.* This hardly differs in appearance from the last; for fine argillaceous matter subjected to certain degrees of metamorphism, especially if containing some carbon, much resembles plumbago or black lead.

5. *Amphibolic.* This takes amphibole, in the form of hornblende, into its composition, in such quantity as to give it a character. But it does not usually pass into hornblende schist.

Garnets and staurotidæ sometimes in like manner impart peculiar characters to mica schist, and make the varieties to be properly called garnetiferous and staurotidiferous.

6. *Spangled mica schist.* The basis of this variety is usually arenaceous, and it is thus described in the Final Report on the Geology of Massachusetts, where it was first pointed out. "Through the base are disseminated numerous thin foliated plates of a deep brown color, resembling mica somewhat, but almost entirely destitute of elasticity, and brittle. Their length (rarely more than a quarter of an inch) is usually twice as great as their breadth, and there is a decided polarity exhibited in their arrangement, that is, their longer axes all lie in the same direction, and the surfaces of the plates in the same or in parallel planes; so that light is reflected from many of them at once when the specimen is held in a proper position, and thus a beautifully spangled appearance results. Not being confident as to the nature of this mineral, I have given the rock a designation which indicates merely this obvious property. These spangles are pretty uniformly diffused through the mass, and their surfaces rarely coincide with the layers of the slate." —page 594.

To this description, based upon this variety of mica schist found on the east slope of Hoosac Mountains in Massachusetts, we are now able to make some addition. For it occurs more or less through nearly the whole extent of Vermont, but in the northern part of the State it has a remarkable development. The peculiar micaceous mineral above noticed increases in quantity until, as in the south part of Derby, it forms most of the rock. It frequently, too, shows itself in distinct rhomboids, nearly half an inch long, and Prof. C. U. Shepard, who regards it as an undescribed species, proposes for it the name of *Adamsite*, in honor of the late Prof. Adams. But more of this under a subsequent head. We say here only, that the rock containing it is made by it a distinct variety from the common mica schist. The characters of the mineral are remarkably uniform throughout the 200 miles in extent where we have observed it. Whether it forms a distinct species as a mineral or not, we think it characterizes a distinct variety of rock.

7. *Feldspathic.* A small amount, but not much of feldspar, may enter into the composition of this rock, and yet the characteristics of mica schist remain so prominent that we can hardly call the rock gneiss, especially if the great mass of the formation be schist. Precisely where to draw the line, however, between these rocks, when we admit the smallest quantity of feldspar to be present in mica schist, is no easy task. And it has perplexed us exceedingly in regard to a large part of the rock in the Green Mountains. Though feldspar be present in it, most of it has the aspect of mica schist; and at first we were inclined to call it feldspathic mica schist, as stated elsewhere. But other considerations have decided us to describe it as gneiss. Yet in other parts of the State we have met with a few examples which we place under this variety of feldspathic mica schist.

8. *Calciferous mica schist.* This is the calcareo-mica slate of Professor Adams, and has been already partially described. We prefer the name *calciferous* to *calcareo-mica schist* as being rather more appropriate and euphonical. For in general the basis of the rock is mica schist, which *bears* the limestone. On the great belt of this rock, running through the whole State, the amount of the limestone increases as we go northerly, and near the north end it is also purer and of a lighter color. Passing south into Massachusetts, the formation again expands, but the amount of calcareous matter is probably less. This rock has a good many interesting relations, which will be noticed in the proper place.

9. *Conglomerate mica schist.* This is uncommon, but sometimes met with. The pebbles are generally quartz, and not large. The variety of schist in which we have noticed the conglomerate character most distinctly is gneissoid, that is, a little feldspar is present.

Beds and irregular masses of quartz are the most usual interstratified rock in this formation, though granite sometimes forms beds in it. Other beds are clay slate, plumbaginous slate, hornblende, and talcose schists and gneiss. There are dikes of trap and veins of granite and of copper.

Divisional Planes.

These are three: stratification, foliation, and joints. We have noticed no cases where the stratification and schistose structure did not essentially coincide, though often one or the other was obscure, very probably because there was a discordance of this kind, which careful study might have traced out.

STRIKE AND DIP.

The following examples of the dip and strike of the calciferous mica schist have been measured:

CALCIFEROUS MICA SCHIST.

[The locality, strike and dip, and initials of the Observer are given.]

Guilford (Algiers), strike N. 20° E., dip 55° E., C. H. H. Guilford, north part, strike N. 5° E., dip 75° E., C. B. A. Guilford, north part, strike N. 12° E., dip 75° E., C. B. A. Guilford, strike N. 20° E., dip 85° E., C. H. H. Guilford, strike N. 20° E., dip 55° E., C. H. H. Guilford, center, strike N. 20° E., dip 55° E., C. H. H. Guilford (Green River valley), strike N. 20° E., dip 25° W., C. H. H. Guilford, do., strike N. 20° E., dip 50° W., C. H. H. Halifax, east part, strike about N. 20° E., dip 89° W., C. H. H. Halifax center, strike N. 45° E., dip 90°, C. H. H. Brattleboro, west of village, strike N. 28° E., dip 50° E., C. H. H. West Brattleboro, strike N. 10° E., dip 24° E., C. B. A. West Brattleboro, strike N. 28° E., dip 67° E., C. H. H. West Brattleboro, strike N. 28° E., dip 38°–45° W., C. H. H. West

Brattleboro, strike N.E. and S.W., dip 85° W. and 85° E., C. H. H. Brattleboro, strike N. 8° E., dip 57° E., C. B. A. Brattleboro, north part, strike N. 8° E., dip 60° E., C. B. A. Marlboro, east part, strike N. 3° W., dip 65° E., C. B. A. and C. H. H. Marlboro, east part, strike N. 8° E., dip 73° E., C. H. H. Dummerston center, strike N. 20° E., dip 51° E., C. H. H. Dummerston, Black Mountain, strike N. 70° E., dip 50° N.W., C. H. H. Dummerston, West River, strike N. and S., dip 60° E., C. B. A. Dummerston, north part, strike N. 70° E., dip easterly, A. D. H. Dummerston, north part, strike N. 40° E., dip easterly, A. D. H. Newfane, east part, strike N. 30° E., dip 80° W., C. H. H. Williamsville, strike N. 30° E., dip 65° E., C. H. H. Fayetteville, strike east of north, dip 50° E., C. H. H. Rockingham, southwest part, strike N. and S., dip 80° W., C. B. A. Rockingham, west part, strike N. 20° E., dip 60° E., C. H. H. Rockingham, north part, strike N. 20° E., dip 60° E., C. H. H. South Springfield, strike N. 25° E., dip 65° E., C. H. H. Weathersfield, northeast corner, strike N. 10° E., dip 60° E., C. H. H. Weathersfield, north part, strike N. 10° E., dip 58° E., C. H. H. Proctorsville gulf, strike N. 20° E., dip 60° W., C. H. H. Proctorsville, strike N. 18° E., dip 85° W., C. H. H. Reading, northeast part, strike N. 30° E., dip 25° E., C. B. A. Reading, northeast part, strike N. 80° E., dip 20° N., C. B. A. Reading, northeast part, strike N. 20° W., dip 20° E., C. B. A. Woodstock, west part, strike N. 20° E., dip 30° E., C. H. H. Woodstock, strike N. 20° E., dip 34° W., C. H. H. Woodstock (Taftsville), strike N. 70° W., dip 20° S., C. H. H. Quechee Village, strike N. 35° E., dip 45° E., C. H. H. Woodstock, north part, strike N. 16° E., dip 35° W., C. B. A. Hartford, southwest part, strike N. 37° E., dip 65° W., C. B. A. Hartford, southwest part, strike N. 80° E., dip 25° S., C. B. A. Hartford, strike N. 8° E., dip 50° E., C. B. A. Hartford, strike N. and S., dip 50° E., C. H. H. Hartford, strike N. 20° E., dip 50° E., C. H. H. Hartford, strike N. 30° E., dip 85° E., C. B. A. Windsor, south of village, strike N. 25° E., dip 43° E., C. H. H. Brownsville, strike N. 10° E., dip 33° E., C. H. H. Windsor, Mount Ascutney, strike N. 10° W., dip 90°, C. H. H. Windsor, strike N. 10° E., dip 55° E., C. H. H. Hartland, strike N. 20° E., dip 61° E., C. H. H. Norwich, strike N. 30° E., dip 79° E., C. H. H. Thetford, northwest part, strike N. 3° E., dip 87° E., C. B. A. Thetford, northwest part, strike N. 3° E., dip 70° E., C. B. A. Thetford, west line, strike N. 10° E., dip 90°, A. D. H. Strafford, pyrites mine, strike N. 10° E., dip 50° E., C. H. H. and A. D. H. Strafford, do., adit., strike N. 10° E., dip 74° E., A. D. H. Strafford, south part, strike N. 10° E., dip 72° E., A. D. H. Strafford, southeast part, strike N. 47° E., dip 30° N.W., C. B. A. Strafford, southeast part, strike N. 10° E., dip 80° E., C. B. A. Strafford, middle, strike N. and S., dip 20° E., C. B. A. Strafford, middle, strike N. 10° W., dip 38° E., C. B. A. Sharon, east part, strike N. 20° E., dip 45° E., A. D. H. Sharon, strike N. 10° E., dip 80° W., A. D. H. Sharon, strike N. 20° E., dip 70° W., C. B. A. Sharon, strike N. 15° E., dip 40° W., C. B. A. Royalton, east part, strike N.E. and S.W., dip 40° N.W., A. D. H. South Royalton, strike N.E. and S.W., dip 48° W., A. D. H. South Royalton, strike N. 10° E., dip 70° W., C. B. A. South Royalton, strike N. and S., dip 55° E., C. B. A. South Royalton, strike N. 40° W., dip 42° N.E., A. D. H. Royalton, dip 20° N.W., A. D. H. Royalton, dip 30° northerly, A. D. H. East Bethel, strike N. 5° E., dip 60° E., C. B. A. Bethel, strike east of north, dip 60° E., A. D. H. Tunbridge, east part, strike N. 10° E., dip 45° W., C. B. A. West Fairlee, strike N. 10° E., dip 54° E., C. H. H. West Fairlee, southwest corner, dip 25° E., C. H. H. West Fairlee, strike N. 3° E., dip 50° E., C. B. A. West Fairlee, strike N. 40° W., dip 33° N.E., C. B. A. Vershire, copper mine, strike N. 20° W., dip 40° E., C. H. H. Vershire, middle, strike N. 60° W., dip 25° N., C. B. A. Bradford, strike N. 25° W., dip 30° E., C. B. A. Randolph, east part, strike N. 30° E., dip 40° W., C. B. A. Randolph, strike N. 20° E., dip 24° W., C. B. A. Randolph, middle, strike N. 4° E., dip 65° W., C. B. A. Randolph, west part, strike E. and W., dip 48° N., C. B. A. Randolph, west part, strike E. and W., dip 45° N., C. B. A. Braintree, east part, strike N. and S., dip 90°, C. B. A. Chelsea, southwest corner, strike N. 80° W., dip 45° N., C. B. A. Chelsea, south part, strike N. 15° E., dip 20° W., C. B. A. Chelsea, strike N. 35° E., dip 35° W., C. B. A. Chelsea, east part, strike N. 35° E., dip 35° W., C. B. A. Chelsea, north part, strike N. 15° E., dip 20° W., C. B. A. Brookfield, south part, strike N. 3° E., dip 60° W., C. B. A. Brookfield, north part, strike N. 8° E., dip 60° W., C. B. A. Brookfield, north corner, strike N. 30° E., dip 60° W., C. H. H. East Roxbury, strike N. 30° E., dip 75° W., C. H. H. East Roxbury, strike N. 30° E., dip 77° W., C. B. A. Newbury, strike N. 20° E., dip 65° E., C. H. H. Corinth, copper mine, strike N. 8° E., dip 46° E., C. H. H. Topsham, center, strike N. 15° E., dip 75° E., A. D. H. Topsham, south part, strike N. 20° W., dip 30° E., C. B. A. Washington, east part, strike N. and S., dip 55° E., C. H. H. Washington, village, strike N. 20° E., dip 40° W., C. H. H. Washington, west line, strike N. 20° E., dip 54° W., C. H. H. Williamstown, east part, strike N. 30° E., dip 56° W., C. H. H. Williamstown, strike N. 10° E., dip 83° W., C. B. A. Williamstown, south part, strike N. 10° E., dip 59° W., C. B. A. Williamstown, strike N. 14° E., dip 57° W., C. B. A. Williamstown, Gulf Spring, strike N. 20° E., dip 40° W., C. B. A. and C. H. H. Williamstown, west part, strike N. 20° E., dip 74° W., C. B. A. Barre, east part, strike N. 30° E., dip 85° W., A. D. H. Barre, middle, strike N. 20° E., dip 40° W., C. B. A. Barre, strike N. 20° E., dip 70° W., C. B. A. Barnet, Stevens village, strike N. 40° E., dip 80° E., C. H. H. Barnet, strike N. 35° E., dip 80° E., A. D. H. Barnet, east part, strike N. 10° E., dip 75° E., C. B. A. Barnet, east part, strike N. 12° E., dip 75° E., C. B. A. Peacham, Four Corners, strike N. 25° E., dip 45° E., C. H. H. Cabot, lower village, strike N. 55° E., dip 55° S.E., A. D. H. Cabot, strike N. 85° E., dip 45° S.E., A. D. H. Cabot, strike N. 35° E., dip 44° N.W., C. B. A. Marshfield, village, strike N. 60° E., dip 55° N.W., C. H. H. Marshfield, west part, strike N. 20° E., dip 67° W., C. B. A. Marshfield, west part, strike N. 20° E., dip 58° W., C. B. A. Marshfield south part, strike N. 8° E, dip 75° W., C. B. A. North Montpelier, strike east of north, dip 35° W., C. H. H. Calais, east part, strike N. 30° E., dip 44° W., C. B. A. Woodbury, east part, strike N. 85° W., dip 68° N., Z. T. Woodbury, south part, strike N. 80° W., dip 50° N., C. B. A. Woodbury, south part, strike N. 80° W., dip 50° N., C. B. A. Hardwick, south part, strike N. 35° E., dip 80° W., C. B. A. South Hardwick, strike N. 20° E., dip 85° E., C. H. H. Hardwick, strike N. 40° E., dip 40° E. & 40° W., C. H. H. Hardwick, middle, about horizontal, C. H. H. North Hardwick, strike about 75° east of north, dip 25°–40° northerly, C. H. H. Walden, strike N. 60° W., dip 20° N., A. D. H. Walden, east part, strike E. and W., dip 20° N., C. H. H. Danville, strike N. 55° W., dip about 15° N.E., A. D. H. Danville, center, strike N.W. and S.E., dip nearly horizontal, A. D. H. Danville, west part, strike N. 40° W., dip 15° N.E., C. B. A. St. Johnsbury, south part, strike N. 25° E., dip 57° E., C. B. A. St. Johnsbury, center, strike east of north, dip about 30° generally, C. H. H. St. Johnsbury, north part, strike east of north, dip 60° E., C. H. H. Lyndon, north part, strike N. 40° E., dip 75° E., C. H. H. Wheelock, west part, strike N. 55° W., dip 20° N.E., C. H. H. Wheelock, strike E. and W., dip 23° N., C. H. H. Wheelock, near village, strike about E. and W., dip 6° N., C. H. H. Wheelock, near village, dip 12°–15° northerly, C. H. H. Wheelock, village, strike E. and W., dip 25° N., C. H. H. Greensboro, south part, strike N. 32° E., dip 85° S.E., C. B. A. Greensboro, center, strike E. and W., dip 60° N., C. H. H. Greensboro, east of do., strike N. 65° E., dip 65° N., C. H. H. Greensboro, two miles east of center, strike N. 65° E., dip 35° N., C. H. H. Greensboro, east part, strike N. 35° E., dip 40° W., C. H. H. Greensboro, north part, strike N. 30° E., dip 48° E., S. R. H. Greensboro, north part, strike N. 30° E., dip 75° E., S. R. H. Greensboro, north part, strike N. 50° E., dip 40° S.E., S. R. H. Greensboro, northwest part, strike N. 50° E., dip 40° S.E., S. R. H. Craftsbury, east part, strike N. 25° E., dip 75° E., C. B. A. Craftsbury, east part, strike N. and S., dip 10° E., S. R. H. Craftsbury, east part, strike N. 30° W., dip 10° S.W., S. R. H. Craftsbury, Presbyterian church, strike N. 30° W., dip 10° S.W., S. R. H. Craftsbury, near do., strike N. 50° E., S. R. H. Craftsbury, Ketchum's Mills, strike N. 30° W., dip 30° N.E., S. R. H. Craftsbury, north part, strike N. 20°–40° E., dip westerly, S. R. H. Craftsbury, common, N. 10°–30° E., dip 30°–40° E., S. R. H. East Burke, strike N. 65° W., dip 50° S.E., S. R. H. Burke Hollow, strike N. 22° E., dip 20° E., S. R. H. Sutton, strike N. 10° E., dip 6° E., S. R. H. Sheffield, strike N. 40° E., dip 50° N.W., S. R. H. Glover, east part, strike N. 10° W., dip 69° W., S. R. H. Glover, village, strike N. 15° W., dip 70° W., S. R. H. Glover, strike N. 24° W., dip irregular, S. R. H. Glover, south of village, strike N. 25° W., S. R. H. Glover, two miles south of village, strike N. 25° E., dip 65° W., S. R. H. Glover, Runaway Pond, N. 15° E., dip east, S. R. H. Glover, west of Runaway Pond, strike N. 20° E., dip 50° W., S. R. H. Charleston, southwest part, strike N. 45° E., dip 60° N.W., S. R. H. Charleston, strike N. 45° E., dip 50° N.W., C. H. H. Charleston, Buck's tavern, strike N. 25° E., dip 70° W., S. R. H. Brighton, west line, strike N. 10° W., dip 74° W., C. H. H. Westmore, northwest part, strike N. 45° E., dip 30° N.W., S. R. H. Westmore, east side Willoughby Lake, strike east of north, dip 90°, C. H. H. Westmore, west part, strike N. 40° E., dip 27° N.W., S. R. H. East Brownington, strike N. 48° E., dip 27° N.W., S. R. H. Brownington, strike N. 53° E., dip 35° N.W., C. H. H. Brownington, strike about N.E. and S.W., dip 30° N.W., S. R. H. Brownington, center, strike N. 50° E., dip 40° N.W., S. R. H. Brownington, west of do., strike N. 70° E., dip 60° N.W., S. R. H. Brownington, center, strike N. 70° E., dip 40° N.W., S. R. H. Brownington, north of center, strike N. 60° E., dip 46° S.E., C. H. H. Brownington, south part, strike N. 45° E., dip 40° N.W., S. R. H. Barton Falls, strike N. 30°–35° E., dip 50°–70° N.W., S. R. H. Coventry Narrows, N. 40° E., dip 46° NW., S. R. H. Salem, west part, strike N. 30° E., dip 65° E., C. H. H. Salem, Arnold's Mills, dip high to east, C. H. H. Holland, southeast part, strike N. 35° E., dip 35° N.W., S. R. H. Holland, strike N. 20° E., dip 40° W., S. R. H. Holland, strike N. 10° W., dip 42° W., S. R. H. West Holland, strike N. 10° W., dip 60° W., S. R. H. Derby, east part, strike N. and S., dip 90°, S. R. H. Derby, center, strike N. 20° E., dip 40°–60° W., S. R. H. Derby, south town line, strike N. 70° E., dip 11° N.W., C. H. H. Derby, south part, strike N. 70° W., dip 15°–30° W., E. H. Derby, west of do., dip very irregular, E. H. Derby, two miles west of village, strike N. 30° E., dip 80° S.E., S. R. H. Derby, west part, strike N. 40° E., dip 70° S.E., S. R. H. Derby village, strike N. 10° E., dip 80° E., C. H. H. Albany, southwest corner, N. and S., dip 60° W., C. B. A.

Average strike N. 31° E. — 11° = N. 20° E.

ALTERED MICA SCHISTS IN NORTHEASTERN VERMONT.

Canaan, northeast corner, strike N. 44° E., dip 65°–80° W. (46° W. true dip), C. H. H. Canaan, east part, strike east of north, dip 25°–69° E., C. H. H. West Stewartstown, N. H., strike east of north, dip 30° E., C. H. H. Canaan, strike N. 50° E., dip 60° N.W., S. R. H. Canaan, west part, strike N. 40° E., dip 82° N.W., S. R. H. Morgan, east part, dip northwesterly, S. R. H. Morgan, Four Corners, strike N. 40° E., dip 20° N.W., S. R. H. Morgan, west part, strike N. 32° E., dip 40° N.W., S. R. H. Lemmington, south line, dip 15° E., C. H. H. Brunswick, north line, strike N. 35° E., dip 90°, C. H. H. Brunswick, east part, strike N. and S., dip 25° W., C. B. A. Bloomfield, southeast part, strike N. 30° E., dip 65° N.W., S. R. H. Columbia, N. H., strike east of north, dip 25° E., C. H. H. West Guildhall, strike N. 55° E., dip 74° W., C. H. H. Granby, east part, strike N. 40° E., dip 80° S.E., S. R. H. Granby, strike N. 55° E., dip 80° S.E., C. H. H. Granby, north of church, strike N. 80° E., dip 80° S., S. R. H. Granby, strike N. 15° E., S. R. H. Victory, strike N. 60° W., dip 55° S.E., C. H. H. Victory, west part, strike N. 20° E., dip 45°–50° E., S. R. H. East Burke, strike N. 20° E., dip 40° E., S. R. H. Tuckerman's Ravine, N. H., dip 28° westerly, C. H. H. Top Mount Washington, N. H., dip 25° N.W., C. H. H. West base of Mount Washington, N. H., dip 30° N. (?), C. H. H.

Mean N. 38° E. — 11° = N. 27° E.

MODIFIED MICA SCHIST.

This occurs mainly in the northeast part of the State. It may have been originally calciferous, and the lime have been abstracted by metamorphism.

Taking the mean strike of 165 observations in the above table for the calciferous mica schist, where the direction is east of the magnetic north, we find it to be N. 31° E. Deducting 10° for variation, and it gives N. 21° E. by the true meridian. In the range of schist in the northeast part of the State, the average strike is N. 28° E. of the true meridian.—In all these cases we have neglected the strikes that are west of the magnetic meridian, which amount to thirty-one examples in the calciferous schist, and two in the other range; because we can hardly doubt that they are the effect of local disturbance, as indeed are probably some of the 165 cases we have used. To make this probable in the calciferous range, if we divide the whole of the list above given into seven portions, in regular order from south to north, the mean of the strikes will be as follows, east of true north:

Number of examples.		*Sum of Strikes.*	*Mean.*	*Number of N. W. Strikes.*
1	26	815	20°	1
2	26	600	12°	3
3	22	444	10°	6
4	30	642	10°	1
5	16	723	34°	3
6	19	794	32°	9
7	26	1031	36°	4

From this table we learn that after getting nearly as far north as Montpelier, the strikes veer a good deal to the northeast. It is also true that the greatest number of westerly strikes are in the vicinity of large outbursts of granite, but this is not invariably the case.

We ought to add that the axis of the whole calciferous formation ranges about N. 10° E. This agrees with the average strikes in the southern half of the formation, but differs considerably from their whole average. Towards the north part of the State the formation curves around more northeasterly, as all others do, to follow down the valley of the St. Lawrence.

Range and Extent.

The principal range of this rock is the calciferous schist. This, as the map shows, extends through the whole State, and occupies, probably, a third of the surface. In the southern part of the State it is narrow, and much of it seems to be replaced by gneiss. Nor can the geologist have much doubt that in some way or other, whether we can or cannot understand the chemistry of the metamorphosis, it has been changed into gneiss. In the neighborhood of Ascutney it is natural to refer such a change to the protrusion of the great mass of granite forming the mountain. But the same effect does not seem to have been produced further north by still larger masses of granite,—and what geologist will suppose the influence of a melted Ascutney could have extended nearly a hundred miles south? The more probable supposition is, that the more general and extended agency that changed the schist into gneiss, produced also the granite. That rock everywhere is found to have played a less important part in uplifts and metamorphisms than was formerly supposed. It seems often to be itself a product of metamorphism.

Of the narrow range of mica schist in the northeast part of the State we can say but little. The foregoing list shows its strikes and dips as observed by us.

*Minerals in the Calciferous Mica Schist.**

These are Black Tourmaline, Scapolite, Spodumene, Rutile, Ilmenite, Garnet, Pyrites, Pyroxene, Feldspar (Orthoclase), Quartz, Washingtonite, Chalcopyrite or Copper Pyrites in immense beds, Kyanite, Calcite, Zoisite, Epidote, Wad, Actinolite, Mispickel, Copperas (alluvial), Galena, Magnetic Iron, Native Copper, Bog Ore (alluvial), Pyrolusite, Malachite, Tufa, Agaric mineral, Staurotide, Albite, Graphite, Marl, Adamsite, Molybdenite.

Tourmaline. The primary form is a rhombohedron often in secondary forms, with trihedral summits. Its colors are black, brown, blue, green, red, and colorless. The chemical composition shows it to contain silicate of alumina, boracic acid, protoxyd of manganese, and in some varieties lithia, soda, lime and potash. The principal ores found in Vermont are the black crystals occurring in pure white quartz, and owing to the contrast between the jet black tourmaline and the milk-white quartz, they form very handsome cabinet specimens. They cannot, however, be used in the place of jet, because they are so extremely brittle that they will not bear cutting. One of the most remarkable localities of tourmaline in the world is at Paris, Me., and its first development is owing to the labors of Prof. C. U. Shepard. The crystals occur of different colors, ranging from pale-pink to garnet-red, as well as green. Some of these have been cut and polished, and form the most beautiful gems hitherto found in the United States. Some varieties of tourmaline which are of a smoke color, are used in the construction of instruments for polarizing light. The principal localities of black tourmaline in Vermont are Newfane, Vershire, Cavendish and Barnet. The specimens of black tourmaline in the State Cabinet are Nos. 277 to 296 inclusive.

Scapolite. This crystallizes in right square prisms, and consists of silicate of alumina, lime, soda and protoxyd of iron. Its localities are in Marlboro, Guilford and Brattleboro.

Spodumene. This mineral is not found in distinct crystals in Vermont, but in Norwich, Mass. In this, the only locality in the world where it occurs in crystals, it is found to be an oblique rhombic prism. Its essential chemical composition is silicate of alumina and lithia, and hence is it a source from which lithia is often obtained. Its color is grayish-white or greenish, and at Norwich, Mass. it often occurs of a pinkish color, probably owing to the manganese in the triphyline, which is found in close connection with it. It has been found as yet only in Brattleboro.

Rutile. This mineral is titanic acid, or the oxyd of titanium. It occurs in shining red crystals, as the term "Rutilus" implies, from which Rutile is derived. In form it is a right square prism. Twin

*By E. Hitchcock, jr.

crystals of it very frequently occur, and sometimes geniculated crystals—or those bent like the knee.—Oxyd of Titanium is used for painting porcelain, and in giving a yellow color to artificial teeth. In Vermont it has been found in Craftsbury, Middlesex, Waitsfield, Montpelier, Moretown, Bristol, Waterbury, Corinth, Norwich, Rochester, Bethel, Marlboro, Dummerston, Putney and Newfane. It may be found in the State Cabinet of minerals, under Nos. 99 to 101 inclusive.

Ilmenite or *Washingtonite* (?) is a mineral of an iron-black color, with a little metallic luster and crystallizing in rhombohedra of 86°. Its chemical composition is peroxyd of iron, and peroxyd of titanium. It is of no economic value as at present known. It occurs in Vermont, in Norwich and Troy. It may be found in the Cabinet under the Nos. 76, 77, 78.

Garnet occurs in the primary form of a cube, although one of its most common secondary forms is the dodecahedron. It has various shades of color, including red, brown, yellow, light-green and black. Garnet is a silicate of different bases; alumina, lime, magnesia, oxyds of iron, manganese and chrome.

The red garnet is used quite extensively as a gem, from its fiery red color and its hardness (being about other the same as that of quartz.) In some superior collections of minerals it is made into vases and ornamental work. When ground into powder, it is used as a substitute (adulteration ?) for emery.—This mineral occurs in Vermont, in the following towns: Halifax, Marlboro, Newfane, Grafton, Cavendish, Chester, Pomfret, Woodstock, Thetford, Charlotte and Peacham. It may be found in the State Collection of minerals under the Nos. 241 to 253 inclusive.

Pyrites, or Iron Pyrites as it is most commonly called, is a bisulphuret of iron. Its primary form is the cube, although it has many modifications. In color it is a characteristic bronze-yellow, with splendent luster. It is always very brittle and gives a spark when struck with steel, so that the name is derived from the Greek which signifies "fire bearing." This is one of the commonest of minerals, occurring as it does in nearly every formation, and is often mistaken for gold. It may always be distinguished from this noble metal, however, by its hardness when scratched with the knife, or its ready crumbling under the hammer. It also gives off a strong ordor of burning sulphur, when exposed to a strong heat. It is often in globular masses, as well as simple crystals. Its economic uses are for making copperas, sulphuric acid, as well as sulphur and alum. At Strafford, Vermont, it is an article of great value in making copperas, as will be mentioned under economic geology. A few localities in Vermont are Alburgh, Fletcher, Shoreham, Strafford, Vershire, Pomfret, Weathersfield, Hartford, Waterbury, Shrewsbury (formerly worked), Arlington, Marlboro and Newfane. It can be seen in the State Collection under Nos. 40 to 50 inclusive.

Pyroxene, of which Prof. Dana gives twenty-two varieties, and Prof. Shepard twenty-six, is a greenish-colored mineral varying from grayish-white to black. In form it is referable to the monoclinic system of Dana, and the oblique rhombic prism of Shepard. It is composed of the silicate of lime, magnesia, protoxyd of iron, manganese or soda. This mineral is one of the most prominent ingredients of some of the igneous rocks, including the recent lavas, and is generally the source of dark-colored metamorphic rocks rocks. It is found in Vermont at the following localities: Newfane, Chester, Ripton (in bowlders) and Jay. Its numbers in the State Collection are from No. 162 to 169 inclusive.

Orthoclase, or Potash Feldspar, of which there are twenty-one varieties described by Prof. Dana, is one of most common mineralogical constituents of primary rock. It is composed of silica, alumina and potash. Its color is white, reddish-white, and sometimes green, with a vitreous luster, and often quite transparent. Its form is probably referable to the oblique rhombic or rhomboidal prism. The principal economic value of this mineral is the manufacture of pottery, it being the basis of all clays. Some of its best localities in Vermont are Corinth, Strafford, Norwich, Chester, Newfane, and Saxton's River. Its numbers in the Cabinet are from 271 to 275 inclusive.

Quartz is one of the commonest of all minerals, and enters largely into the composition of nearly all known rocks. Its primary form is that of the rhombohedron, though its most common mode of occurrence is the hexagonal prism. Its chemical composition is nearly pure silica. The colors which it assumes are nearly all those of the rainbow. It occurs in crystals and masses which are perfectly transparent, and in others which are absolutely opaque and black as jet. Some crystals have been found of very great size.—

One crystal was found in Waterbury which is 2 feet long and 18 inches through, which weighs 175 pounds. Another from Roxbury, now in Middlebury College Cabinet, is 20 inches long and 11 inches in diameter. A few of the more prominent localities of quartz in Vermont are Waterbury, Roxbury, Lyndon, Alburgh, Saxton's River, Grafton, Chester, Hartford, Sharon, Corinth, Middlebury. The specimens in the State collection are from No. 134 to 157 inclusive. Several gems are merely varieties of quartz. Thus the amethyst—which when surrounded with pearls and set in gold is highly prized—is simply quartz which is probably colored with oxyd of manganese. The Scotch cairngorm is smoky quartz, and carnelian agate, jasper, heliotrope, sardonyx, onyx, and cats-eye, belong to this species.

Washingtonite. (See Ilmenite.)

Chalcopyrite, or Copper Pyrites. This is principally an ore of sulphur and copper, though iron is often found with it. Whether, however, the iron is properly a constituent of the chalcopyrite, or is only a constituent of the iron pyrites that is almost universally found with it, seems to be a matter of some doubt with mineralogists. It crystallizes in right square prisms for the primary form. The color is brass-yellow. It is the ore from which a large part of the copper of commerce is manufactured, being the one found in the Cornish mines in England. It is found in this country in workable quantities in Tennessee, Georgia, and Bristol, Conn. Large deposits of it exist in Strafford, Shrewsbury and Vershire, Vt. It also is found in smaller quantities in Middlebury, Thetford, Vershire, Corinth, Ludlow, Sterling, Waterbury. It can be found in the Cabinet under Nos. 22 to 33 inclusive.

Kyanite. This mineral of a beautiful transparent blue color, crystallizes in long flat crystals which are regarded by Dana as belonging to the oblique rhomboidal prism. Its chemical composition is silicate of alumina, with traces of iron in some specimens. Of the cause of the blue color no chemical analysis as yet has given us any clue. When the crystals are large and transparent, they are used for gems. It occurs in Vermont at Bellows Falls, Chester, Hartford, Norwich, Sharon and Thetford. It may be seen in the State collection under the Nos. 284–5–6.

Calcite, or Calcareous Spar. This is known to the chemist as carbonate of lime. Its primary form is a rhombohedron, while its secondary forms number more than a hundred. Its luster is vitreous, and when broken even by the blow of a hammer, it at once shows many of the primary planes. The prevailing color is white, although black calcite not unfrequently occurs. In this case the black is owing to some impurity. Intermediate colors of gray, green and yellow are sometimes found. As calcite is the basis of all marbles, this mineral will be further treated of under Economic Geology, by Mr. Hager, and excellent specimens of marbles will be found in the Geological Collection. Crystals of calcite are found in Vergennes, Burlington, Colchester, Whitingham, Hartford, Danby, Dorset, Alburgh and Craftsbury. Specimens are found in the State Collection numbered from 327 to 352 inclusive. These, however, include some limestone and stalactite.

Calcareous Tufa is a deposit of calcite from water upon loose rocks, organic matter, &c., and sometimes has a distinct cleavage. Where it is deposited upon vegetable stems, it often makes a complete mould of them. When it is deposited from the roofs of caverns and cavities in rocks, and forms icicle-shaped and elongated masses, they receive the name of stalactites. When deposited so that it remains friable—in powder—it is then called *agaric mineral,* or *rock milk.* Marl (calcareous), is simply a more impure form of rock milk. The impurity generally is clay. It is of so frequent occurrence everywhere that it is needless to mention localities of it in this Report. Specimens illustrating concretionary and stalagmitic calcite are found under Nos. 349–50–1–2 in the Collection. A specimen of the rock milk, or agaric mineral may be seen under No. 353. Marl is found at Highgate, Barnet, Danville, Hardwick, Peacham, Woodbury, Barre, Calais, Brookfield, Corinth, Tunbridge, Westminster, Royalton, Barnard, Woodstock, Albany, Coventry, Greensboro, Holland, Ryegate and Walden.

Epidote, including *Zoisite.* Epidote crystallizes in oblique rhombic prisms for its primary form. Its chemical composition is principally silicate of alumina, iron and lime. Occasionally it contains manganese. It has a vitreous luster, is generally subtransparent or subtranslucent, and is of a green, brown or gray color. Epidote is a common mineral, but it is not often in well defined crystals. Zoisite, gray epidote, or lime epidote, as it is often called, differs but slightly from epidote, as already described, except in its color, and its occurrence in the variety which is in long fibrous crystals, of a gray or bluish-gray color, and

sometimes radiating from a center. The crystals also cleave easily. Epidote and zoisite are found in Vermont in Berkshire, Enosburgh, Woodstock, Chester, Norwich, Wardsboro, Westminster, and Middlebury. In Cabinet under Nos. 226 to 240 inclusive.

Wad. This is an earthy oxyd of manganese, which occurs without a crystalline form, and is not of a definite chemical composition. It consists mainly of oxyds of manganese and water, some oxyd of iron, and often alumina, silica, lime or baryta. Its color is black, bluish or brownish-black. It occurs as a marsh deposit, and in some instances has been regarded as the product of decomposing brown spar. Sometimes it is used as a coarse pigment, and sometimes in the manufacture of glass. It occurs in Vermont at Moretown, Monkton, Topsham, Poultney, Norwich, Pomfret, Irasburgh, Lowell, Warren. Nos. 131, 132 and 133 in the Cabinet are specimens of wad from three localities in Vermont.

Glassy Actinolite. This is merely a variety of hornblende, which will be described in another part of this Report. It occurs in light-green, bladed crystals, which break easily across the prism. The green color is said to be due to the iron present. It is one of the most attractive minerals occuring in Vermont, since it is found in the steatite or talc of nearly a white color, which forms a very beautiful contrast with the shining green actinolite. It is found in Warren, Waterville, Reading, Bethel, Cavendish, Readsboro, Marlboro, Newfane, Townshend and Windham. Specimens of it can be seen in the State Cabinet under Nos. 187 to 196 inclusive, and 201.

Mispickel, or Arsenical Iron, is a mineral of a grayish-white color (between silver-white and slate-gray), with the primary form a right rhombic prism. Its composition is arsenic, sulphur, iron, and in some specimens a trace of cobalt. This occurs in Vermont at Brookfield, Waterbury, Stockbridge, Vershire, and Bethel. No. 37 in the Cabinet is a specimen of Mispickel.

Copperas. This mineral generally occurs in stalactite reniform masses and crusts, though its crystalline form is referable to the oblique rhombic prism. Its color is green passing into white, becoming yellow on exposure. It is a sulphate of iron in chemical composition, and is generally found as an efflorescence from decomposing pyrites. It occurs at Strafford, Shrewsbury and Corinth in connection with the decomposing pyrites.

Galena, or Sulphuret of Lead. Galena crystallizes in cubes, and has a very perfect cleavage of the cube. Its composition is simply sulphur and lead, its luster metallic, and its color lead-gray. When found in the older rocks it is usually associated with silver, sometimes containing 70 ounces to the ton, when it is called a rich argentiferous galena. If the amount does not exceed 10 ounces to the ton, it will not pay for the extraction. The best localities for lead in this country are in Missouri, Iowa, Wisconsin, and Illinois. In one locality not exceeding 50 yards square, 3,000,000 lbs. of lead have already (1857) been extracted. Galena occurs in Vermont in Corinth, Thetford, Chittenden, Bridgewater (where it contains silver 25 oz. to the ton), Plymouth, Brandon, Morristown (rich in silver.) It can be seen in the Cabinet under Nos. 11 to 17 inclusive.

Magnetite, or Magnetic Iron Ore. This mineral is ordinarily seen in octahedrons, but its primary form is a cube; it has a metallic luster. It is an oxyd of iron, and one from which is usually made the best of iron. It is especially good for the manufacture of steel. As its name implies, it shows magnetic properties, when placed near or in contact with a magnet. It occurs in Vermont at Middlebury, Warren, Brighton, Berkshire, Enosburgh, Troy, Lowell, Craftsbury, Pomfret, Rochester, Bethel, Bridgewater, Cavendish, Chester, Norwich, Plymouth, Ludlow, Somerset, Marlboro, Shrewsbury, Chittenden, Corinth, Strafford, and Mendon. It may be seen in the Cabinet under Nos. 55 to 61.

Native Copper. This when crystallized has the primary form of the cube. Octahedral crystals are sometimes found. As its name implies, it is of pure copper. Often it is associated with native silver, and in some of the Lake Superior mines this is found in as great quantities as 7 or 8 per cent. It is found in Vermont at Strafford, Vershire and Bridgewater. The only specimen in the State Collection is from Strafford, and is No. 5.

Fasciculite (included under hornblende.)

Bog Ore. This is but a variety of limonite, which is known as the hydrous peroxyd of iron. It does not occur in a crystalline form, but is either stalactitic, botryoidal or mammillary, with a fibrous structure.

Bog ore is usually found in low, marshy places, as a result of the decomposition of other ores of iron, and often incrusts plants, wood, &c. Limonite is one of the most widely diffused species of iron in the United States, and yields a large quantity of the metal. It is however principally used for castings, since it is *cold short*, as the term is, and cannot be used for wire, or where toughness is required. It is found in Vermont at Colchester, Milton, Bristol, Huntington, Ripton, Starksboro, Warren, Wallingford, Highgate, Swanton, Guilford, Bennington, Dorset, Manchester, Pittsford, Brandon, Chittenden and Strafford. It can be seen in the State Cabinet under Nos. 102 to 122 inclusive.

Pyrolusite, or the Anhydrous Binoxyd of Manganese, with sometime a trace of silica and baryta, is a common ore of manganese. In primary form it is a right rhombic prism. Its color is bluish-black, though in some instances, as at Chittenden, it occurs in brilliant steel-gray crystals. It is often found in connection with the other ores of manganese. In Vermont it occurs at Chittenden, Bennington, Brandon, Irasburgh and Monkton. It may be seen in the State collection from Nos. 79 to 90.

Malachite, or Green Carbonate of Copper, is composed of protoxyd of copper, carbonic acid and water.—It is seldom found in a crystalline condition, but generally in fibrous botryoidal or stalactitic masses. Its primary form, however, is referable to the oblique rhombic prism, and this often in twin crystals. It is of a beautiful green color, and when in large masses and sufficiently compact, it is made into table tops, vases, and even ornamental jewelry. Such specimens are found in Siberian Russia and Western Africa.—It usually accompanies the other ores of copper, and is considered as originating from them by the action of atmospheric air and water. It is not found in large masses in Vermont, but occurs at Vershire in well characterized specimens. It may be seen in the State Collection, No. 370.

Albite. This mineral, formerly called Cleavelandite, is a silicate of alumina and soda, the latter of which is sometimes partly replaced with potassa, or lime. It is often called a soda feldspar, to distinguish it from orthoclase and Labradorite. Primary form, oblique rhomboidal prism. In color it is pure white, which characteristic is one of the most important physical signs for distinguishing this mineral. It occurs in Cabot and Westmore, and may be seen in the Collection at the State House under Nos. 268, 269 and 270.

Graphite, Plumbago, or Black Lead, is a carburet of iron. It is nearly all carbon, though there is sometimes in it ten per cent. of iron. Other impurities are occasionally found mixed with the carbon. In crystalline form it belongs to the Hexagonal System. It is usually found either fibrous or in six-sided flat plates, with a steel-gray color and a greasy feel, and a black and shining streak. One of the best localities in the world is at Borrowdale, England, and another is Ceylon. It is used for making fire pots, lead pencils, and diminishing friction in heavy bearings. It occurs in Vermont at Brandon, Newbury, Swanton Falls, Pittsford, Norwich, Hancock and Huntington. In the Cabinet it may be found under No. 7.

Staurotide. This mineral receives its name from the Greek word signifying a cross, since one variety of its twin state is a cross. Its crystalline form is a right rhombic prism, and its chemical composition silicate of alumina, iron, and magnesia. In color it is red or reddish-brown, and it has a white streak. It has been found in Vermont at Cabot, Saxton's River, and is in the State Cabinet under Nos. 282 and 282½.

Adamsite. This is regarded as a new Natural History species by Prof. C. U. Shepard. The following is his letter upon it:

"The mineral from Derby, Vt. is the substance which you had ticketed Gigantolite with a query. Its mode of occurrence in thickly disseminated crystals, through mica slate, and its brittleness, would very naturally suggest such an opinion. Its clove-brown color reminded me of Phlogopite. It has the feature of remaining wholly unaltered, even in the most weathered specimens, which assimilates it to Margarite and the Clintonite. Its crystalline form however is that of mica, and but for its perfect inelasticity and greater hardness, it might coalesce with this species. Under these circumstances it appears to constitute a new Natural History species, which with your approbation I should be pleased to call *Adamsite*, after our lamented associate Prof. C. B. Adams, who was also the first State Geologist of Vermont. For the present I must content myself with a very brief description of the species. The crystals are quite uniform in size, about one quarter of an inch in their longest diameter, by less than one twentieth of an inch in height, Form, oblique rhombic prism of 120°. Terminal planes smooth and shining; lateral planes very imperfect

and much coated by flecks of a dark-blackish chlorite? Cleavage parallel with the base of the prism, but effected with much difficulty, the crystals being too brittle to cleave with facility. In this respect the mineral is similar to Clintonite and Orthite, and quite apart from mica. Color by reflected light, clove, or anthophyllite-brown, by transmitted light, bluish gray. Some of the crystals are nearly transparent. When closely viewed, the terminal planes generally present the iridescent-colored rings of Newton. Luster, shining to splendent. Hardness, 2.5 to 3. Gravity 2.71 and 2.83 (according to Prof. Brush.) Before the blowpipe its foliæ expand, the mineral turns silver-white, and in the highest heat passes to a perfectly white enamel or glass. Heated in a glass tube, a little moisture is evolved, attended by a feeble corrosion of the glass, proving the presence of fluorine. Prof. Brush has at my request kindly determined approximately the following points, relative to its chemical composition:

Silica,	47.76
Alumina (with peroxyd of iron, 3 or 4 per cent.),	36.29
Lime,	0.24
Magnesia,	1.85
Alkalies (by loss),	8.77
Volatile matter,	5.09
	100.00

From the chemical investigation, therefore, nothing has been made out incompatible with its belonging to the species mica; but the impurity of the specimens analyzed, owing to the adhesion of chloritic scales, renders desirable a new analysis, before we can say with confidence that its composition is identical with that of mica. It is proposed as a new species wholly on the ground of physical properties. (From a letter of Prof. C. U. Shepard to Prof. Edward Hitchcock, Oct. 22, 1859.) This mineral has been found at Derby, Glover and Newfane, and may be seen in the State Cabinet under Nos. 263, 264, and 265.

Molybdenite, or sulphuret of molybdenum. It crystallizes in short hexagonal prisms. Has a greasy feel and a pure lead-gray color. Resembles in physical characteristics, graphite, but gives a green trace on porcelain. Found at Brighton, and is No. 48 in the State Collection.

Geological Position, Equivalency and Origin.

According to our Sections, as has been already stated, the calciferous mica schist is overlaid by clay slate, and a strong presumption has been shown that the latter is of Devonian age. It would follow if the strata have not been inverted that the mica schist is older, though not necessarily enough older to bring it into the upper Silurian. But such is the position assigned to it by the Canada Survey. (See Mr. Hunt's paper on the Crystalline Limestones of North America, American Journal of Science, Vol. XVIII, p. 198, Second Series.) "These upper Silurian strata," says Mr. Hunt, "constitute the micaceo-calcareous rocks of Vermont which Prof. Adams traced through the State to Halifax on the border of Massachusetts, and they are continued in what Hitchcock has called the micaceous limestones of this State (Mass.), which, according to him, pass by insensible degrees into mica slate." Mr. Hunt regards the enormous mass of mica schist, clay slate and gneiss, intervening between the calciferous schist of Vermont and the coal formations of southeastern Massachusetts, embracing the White Mountains, as Devonian. We have doubts here; for it is at least probable that some of the clay slate along Memphremagog is probably Devonian; and before reaching even the coal field of Worcester, in Massachusetts, we strike another band of clay slate. Moreover, the enormous thickness of gneiss lying between the Worcester coal field and that of Norfolk County have a predominant strike quite different from that of the range between the Worcester and

Connecticut valleys, indicating that they probably belong to different systems of uplift. Is it not more probable that the clay slate once mantled over the strata intervening between these bands of that rock? If so, erosion may have so cut down the middle of the folds as not only to sweep away all the slate, mica schist, and metamorphic gneiss, but sometimes, also, to bring to light the hypozoic or Laurentian rocks. An examination of the sections across Vermont will suggest the inquiry whether these lower rocks are not thus brought to light there in some instances, as we have suggested in another place. Admitting the probability of such an arrangement, we see the need of much further research before we can pronounce with any confidence upon the age of the crystalline rocks of New England, where they are not so connected with the fossiliferous that we can directly infer a sequence. We confess, however, that the geologists of Canada have probably a better opportunity for settling these questions than we have.

In the south part of Derby we have found a section that may throw some light on the age of the calciferous mica schist, as well as some other rocks. It is on the western border of the schist, and much of it has that species of the mica family that has been described as Adamsite; nor have we noticed any limestone in it resembling that generally associated with this schist. But the region is filled with granite which interpenetrates the schist, and both rocks lie above, and are interstratified with fossiliferous limestone, probably the Devonian. The sketch (Fig. 19) will give an idea of this example. The right hand side extends nearly to the stage road from Brownington to Derby, and the first bed of limestone at the foot of the hill is in an open field on the left hand side of the road, on the farm of Mr. Robbins. The granite lies on the limestone very distinctly, even projecting beyond it, as shown on Fig. 301; and the granite sends down veins into it in an interesting manner. Above this granite we find another bed of mica schist, then another mass of granite, then other beds of schist with limestone between them, then granite succeeds, then slate, and so on over the whole hill, and even for at least two miles to Clyde River, near its mouth. It is only the first four beds of granite, beginning at the right, that seem distinctly interstratified with the schist and limestone; for as we get nearer the top of the hill, and so over its crest, the granite, so far as we could judge, seems thrust in more irregularly among the schist, and it may be that all the granite beds are connected with, or proceed from, the same mass of granite on the south side of the hill. But at the most important point of the section the interstratification seems very distinct. The region beyond the top of the first hill and to the Clyde, is covered mostly with woods, and all we can say of it (for we only passed over it once) is, that we found frequently granite in juxtaposition with schist, but often apparently in a very irregular position. Yet, near the clay slate along the Clyde, the granite appears in great force; but it has not much disturbed the slate.

Now, in the limestone underlying the granite in the above section, we found within a foot or two of the granite a few encrinal stems, which unfortunately we lost. But the geologist recognizes this rock as one that is fossiliferous further south in Vermont, and also in Canada, especially at Owl's Head. The fossils there, as we have seen, are probably Devonian. If so, this granite and mica schist are of that age. Whether this would bring the whole of the calciferous schist into that period we doubt; for this spot appears to be near the west border of the schist, and the dip of the strata is west—as it would be

if it formed the upper part of the deposit. The Canada geologists, we believe, have been in the habit of regarding the calciferous schist as of the age of the Niagara group of New York.

Under granite we shall give additional facts respecting this interesting spot.

Origin.

Clay slate often passes by insensible gradations into mica schist, and no dividing line can be drawn between them. Hence we have one of the sources whence mica schist may originate. A comparison of their composition shows that in many cases, but not in all, such a conversion is possible. Sometimes, in consequence of a deficiency of certain ingredients, a rock will be found intermediate between the two.

How much of the pure mica schist of Vermont has been derived from clay slate, it is impossible to say. The principal range of mica schist is the calciferous, and clay slate shows itself along both borders of this, often in connection with that which is not calcareous. Probably this may generally have been metamorphosed clay slate. Indeed where the two rocks pass insensibly into each other, we cannot doubt that such was the case. Mica schist, however, may be derived from any rock that is silicious and contains the ingredients requisite for the production of mica. We know that in some instances it has been derived from chlorite schist and green stone, and some sandstones scarcely require much change to become mica schist. We have also shown how, by a process partly mechanical, and partly chemical, even conglomerate may become mica schist.

What we have called calciferous mica schist exhibits some interesting phases of metamorphism. A considerable part of it would be better described by calling it limestone with intercalated beds of schist. This is especially true as we approach the northern parts of the State. In Canada, Mr. Hunt describes it as belonging to the upper Silurian, sometimes white and crystalline, with "the characteristic fossils of the Niagara group." In Vermont, however, we have never found any fossils—and the rock soon assumes a dark, rough appearance, with projecting masses of quartz and mica schist so obscuring the characters that probably few of the inhabitants suspect the rock to be limestone. The characters become still more obscure as we go southerly, until near Ascutney it is almost entirely changed into, or replaced by, gneiss, as our geological map shows. This rock continues diminishing in width almost to the south line of the State, where the calciferous schist regains considerable width and passes across Massachusetts, losing a good deal of the limestone towards the south part of the State, and becoming more distinctly mica schist. How far it extends into Connecticut we are unable to say; but it runs far to the east of the crest of the Hoosac Mountain, and has no connection with the micaceous limestones of western Connecticut, which are probably of Eolian age. It was not till a few years ago that any persons in Massachusetts imagined that this unsightly rock contained lime enough (it sometimes contains over fifty per cent. of the carbonate) to make it of the slightest value; but it is now sometimes burnt for agricultural purposes. Nor is it known even now that it is the slow decomposition of this rock which produces those fine crops of grass and other products which one meets at the eastern part of the Green Mountain slope, as we ascend from the Connecticut valley, all the way from Connecticut to Canada. The surface is very much broken and the hills steep, yet they furnish some of the richest soil in New England, though often the naked rock occupies a good deal of the surface. Nature, in general, brings out the fertilizing lime, and the rains spread it over the surface just about fast enough, perhaps. Yet it has occurred to us whether by some simple process it could not be made to give it up more rapidly. Suppose, for instance, that upon one of those black looking points of rock that show themselves often in cleared fields within the limits of this formation, a quantity of ashes were spread. Might not some of the carbonic acid of the limestone unite with the potash, and thus prepare two good fertilizers, viz., hydrate of lime and carbonate of potash? We have never made this experiment, and it may not succeed; but we suggest it as one easily tried by any farmer who finds himself located anywhere along that broad deposit which on our map is called calciferous mica schist. And the same experiment might work well over that other wide strip marked as talcose schist; for we have found that much of this rock contains carbonate of lime. Without such an experiment, however, we have already intimated how rich a boon to Vermont is this fact! Of more value, probably, than her marble, slate, granite, and soapstone, especially when we add that nearly all the valleys and moderate slopes west of the Green Mountains are still more abundantly supplied with this fertilizing agent. We are certain that no other New England State will compare at all in this respect with Vermont.

To return to the subject with which we started, viz., the metamorphism of this rock, we are of opinion that it was originally a limestone formation charged with a good deal of silex, and perhaps with silicates and organic matters. In the process of metamorphism the carbonated or alkaline water with which the rock has been charged has dissolved and abstracted a good deal of the carbonate of lime and formed silicated minerals, such as mica and feldspar, which have more or less, and sometimes entirely, changed the rock into mica schist and gneiss. For no one can look at the range of gneiss extending southerly from Ascutney, on our map, without being satisfied that in some way or other the calciferous mica schist south of the region of Ascutney has been mostly changed into syenite, quartz and gneiss. If the schist did not reappear as we go southerly, we might hesitate to say that the gneiss and syenite were forms of its metamorphism; or if the western side of the gneiss did not essentially agree with what would be the western side of the schist were it continuous, we might hesitate. But as it is, and with the evidences of metamorphism which other parts of the State present, we see no way to escape from the conclusion. At any rate, as we go southerly, as a general fact, the calcareous element diminishes and the schistose element increases. Can it be that the narrowing of the formation as we go south, and especially in Massachusetts and Connecticut, should be the result of the abstraction of the lime, so that the lateral pressure was able to bring the residue into a narrower compass!

Perhaps this formation affords the finest examples of changes in a rock on the line of strike which we shall be able to present, though we have some other very good ones. But we have always been jealous of supposing changes on the line of strike, because every geologist knows how difficult it is to follow a rock with certainty on the line of strike in such a region as New England. Where we must cross deep valleys covered with drift, when we reach the opposite hill we are not certain but its strata may be so folded around those we have been tracing as to be parallel to them, and not their prolongation. But the great extent of this formation, not less than 300 or 400 miles, and the great and decided changes which occur, make our conclusions on this subject quite safe.

CLAY SLATE.

BY E. HITCHCOCK, SENIOR.

Whoever will compare a bed of clay where the layers have been deposited quietly above one another, with the slates used for roofing, will notice a strong resemblance of form and composition; and he cannot but suspect that the latter has been derived from the former. He can, if he will, trace out the steps of the process. Clay hardened by the sun and filled with cracks, seems to be a sort of first step in the process. Among the newer sandstones he will see similar layers, called shale, which is sometimes only a little harder than clay, and seems to want only a smoother and glazed surface and induration to form clay slate. These changes are produced in the shales by the more powerful influence of metamorphic agencies, which generally also superinduce other divisional planes in the rock, such as cleavage and joints. But cleavage planes in most of the clay slates of Vermont, coincide essentially with those of deposition; and the slaty layers seem to be mostly strata or laminæ modified. If the modifying force were pressure, it seems to have operated to convert the planes of lamination and stratification into those of cleavage, increasing the number of the latter.

Such being the origin of this rock, we might expect to find it in any formation where the proper action has been sufficiently powerful to indurate, cleave, and glaze it, so as to carry it beyond the condition of mere clay or shales. The same causes may make it also fossiliferous or unfossiliferous. Under the fossiliferous rocks we have already expressed the opinion that all the clay slate of Vermont will be found to contain fossils; because we have only to follow some of the beds a little beyond the State, on the line of strike, to find them in New York and Canada. But since we have met with but few cases of this sort in Vermont, and as the clay slate here is, at least in all the region east of the Green Mountains, associated with unfossiliferous schists, we have thought it best to throw together the most important particulars respecting this rock, under the azoic series, though we shall try not to repeat what we have said respecting the clay slate associated with fossiliferous rocks, in the west part of the State.

Lithological Characters.

These embrace the simple minerals that enter into the composition of the rock, their mode of arrangement, and the varieties that result from the predominance of some of the ingredients, or of the admixture of foreign substances.

1. The varieties in clay slate are few, unless we refer to color. The rock is usually simple and homogeneous, composed of finely comminuted, hardened clay. If it has a good deal of iron, and if this is passing to the state of peroxyd, we shall have red slate, such as is quarried within the limits of New York, and occurs in Vermont, as beneath the bridge over a river at Pawlet Center, where the junction of this red slate and of talcoid schist is well exhibited. The red and gray slates, also, are often shown in the quarries in Castleton, Fairhaven and West Haven. A greenish color also is not unfrequently seen, as in the Welsh quarries.

2. On the margin of the quarries in Dummerston, we found loose fragments of slate filled with small rounded pebbles of purely hyaline quartz. This forms a delicate conglomerate which still, however, retains the slaty structure, though some of the pebbles are nearly two inches in diameter, and though the layers are generally plicated like the schists. We did not find the rock in place, but cannot doubt that it occurs in the vicinity of the quarries.

The nodules of quartz in this rock are not in general flattened, nor is the laminated structure of the cement, properly speaking, cleavage, but more like foliation. But the fact that all the nodules are pure highly crystalline quartz, is interesting. We cannot but regard it as another example and evidence of the abstraction of all other ingredients except the quartz, during the metamorphism of the rock, probably through the aid of organic or carbonaceous matter. The idea that the pebbles were all originally hyaline quartz, is highly improbable, since that is an unusual rock in quantity, and could hardly be abraded without a large admixture of other rocks. The pebbles were probably of various kinds originally, but the quartz alone has survived the decomposing agencies of metamorphism.

3. *Calciferous Clay Slate.* Not unfrequently, especially where the clay slate approaches, or is interstratified with calciferous mica schist, the slate also becomes impregnated with carbonate of lime, and in some cases the impure limestone forms beds in the slate. Where the slate gives a decided character to the rock, it may perhaps be regarded as a variety of clay slate.

4. *Novaculite Slate.* Novaculite differs so much from clay slate, that perhaps it should not be given as a variety of that rock. Moreover it is not confined to clay slate in Vermont, but is often met with in talcose schist. Indeed, it is rather a schist than a slate. But then its thickest beds are found in clay slate, as in Guilford, where the bed is a quarter of a mile in thickness. We have also regarded a rock still more extensive in the northern part of the State, as this rock. Its importance in an economical respect, since good hones will doubtless be manufactured from it, entitles it to a description somewhere, and even of a distinct color upon the Geological Map. We therefore place it as a variety of clay slate, and of talcose schist also.

Divisional Planes.

The most obvious of these is slaty cleavage. In the western part of the State, where the slate is probably of an age somewhat different from that east of the mountains, we see occasionally cleavage planes making an angle with the original stratification. Yet in the same quarries we find also joints—and to distinguish between the three kinds of structure is often quite difficult. In many places, however, we have decided evidence that the slaty cleavage is coincident with the stratification. For beds of other rock are present, and correspond in dip and strike with the cleavage planes. A good example of this sort may be seen just within the limits of New York, in the slate quarry a little north of the village of Middle Granville. The cleavage there dips about 50° E., and the excavations have laid open a bed of sparry limestone, four feet thick, which has the same dip and strike, but it shows no cleavage. In the clay slate east of the Green Mountains, the interstratification of quartz, or mica schist, or novaculite, is not uncommon; and we have rarely, if ever, found the dip and strike of these beds different from the cleavage of the slate.

We have intimated, in another place, that the strike of the cleavage planes, in the slate ranges east of the mountains, does not probably differ much from the general strike of the formation. Approximately to determine this point we have added together all the strikes given below, and find the averages to be as follows. To these we have subjoined the general strike of the formations, as ascertained from our Geological Map. Both are given from the true meridian:

Range along Connecticut River, average strike,	N. 14° E.
Strike of the formation, ...	N. 13° E.
Range from Barnard to Newport, average strike,	N. 14° E.
Strike of the formation, ...	N. 13° E.
Range running south from Troy, average strike,	N. 8° E.
Strike of the formation, ...	N. 8° E.

The variation of the magnetic needle from the true north, according to the report of the Smithsonian Institution, is 11° W., in northeastern Vermont, and 9° W., in the southwest part; the average, 10°, we have used above. And though from the random manner in which the strikes have been taken, they can give no very close approximation to the average strike of the formation, and though the observations on the limited range of slate running through Troy are few, yet the near coincidences above given between the average observed strikes and that from the map show a very close coincidence.

One of our number (A. D. Hager) has attempted to measure the different dips and strikes of the different structures in some of the slate quarries in Western Vermont, and we give the following examples from his notes:

At Myers' and Utter's slate quarry, one mile north of Fairhaven:

Strike of the strata, ...	N. 30° E.
Strike of the cleavage planes, . .	N. 20° E.

On the hill east of the quarry:

Dip of the strata, ...	10° E.
Dip of the cleavage planes, . . .	34° E.
Strike of the joints, ...	N. 40° W.

At Wilbur's quarry, near that of Myers' and Utters:

Cleavage dip, ...	15° E.
Strata planes, ...	10° E.
Strike of both, ...	N. 15° E.
Dip of joints, ...	40° E.

At Williams & Tyson's quarry, thirty or forty rods north of Wilbur's:

Cleavage dip, ...	12° E.
Strata planes, ...	5° E.
Strike of both, ...	N. and S.
Joints, nearly	90° E.

Another quarry of Williams & Tillson:

Cleavage dip, ...	10° S. E.
Strata planes, ...	10° E.
Strike, ...	N. 10° E.

Lloyd, Jones & Co.'s quarry:

Strike of layers, ...	N. 30° E.
Cleavage dip, ...	21° S. E.
Strata planes, ...	17° E.

At Allen's south quarry, in east part of Fairhaven:

Cleavage dip, ...	20° N. E.
Strata planes, ...	10° E.
Dip of joints, ...	N. 70° E.

The Eagle slate quarry, in Fairhaven:

Cleavage and strata planes both dip .	20° E.
1st set of joints dip	60° E.
2d set of joints dip	N. 80° E.

At the West Castleton Railroad and Slate Company's quarry:

Strike, ...	N. 10° E.
Cleavage dip, ...	40° E.
Strata planes, ...	50° E.
Joints, strike E. and W., dip . .	70° S.

Quarry near Bombazine Lake:

Dip of strata, ...	10° E.
Dip of cleavage planes, ...	30° E.

The mean strike of the east range of the longest and easterly belt of the Rutland County slate, is N. 21° E., by compass, or N. 11° E., by the true meridian. The strike of the formation by map is N. 7° E. Difference 4°.

Mean strike of the western belt in Rutland County, N. 23° E., or N. 13° E. of true north. Strike of formation N. 7° E. Difference 6°.

Mean strike of Franklin County slate, N. 25° E.—10°=N. 15° E. Strike of the formation N. 14° E. Difference 1°.

All these differences are not greater, perhaps, than can be explained by the difficulty of measuring accurately the strike of the formation, and the conclusion as to the western slates, as it was respecting those east of the mountains is, that the strike of the cleavage planes and of the formations correspond.

Very perfect rhomboidal joints are not unfrequent in the clay slate on a small scale. We copy Fig. 271 from Professor Adams' Report, showing a rather peculiar form from Dummerston.

Fig. 271.

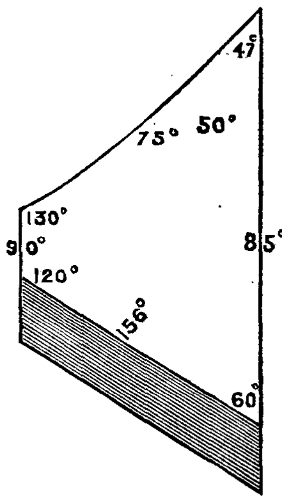


Fig. 272.

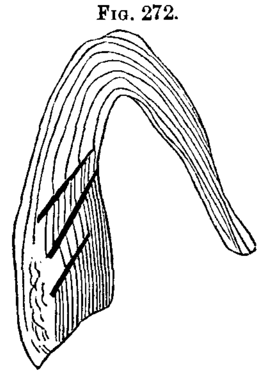
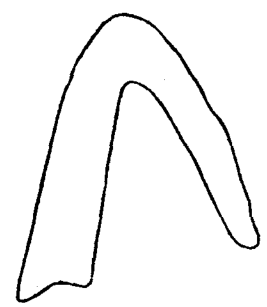


Fig. 273.



Sometimes a succession of joints is seen very near to one another, along which there have been short slides, not enough to break the slate entirely, but only to throw the pieces into what, in military movements, is called an *echellon* form, of which we have given a sketch on page 559 of the Final Report on Massachusetts. The specimen was found at Bruce's quarry, in Guilford. At the same place striking plications on a small scale sometimes occur, of which Figs. 272 and 273 are examples, copied from Professor Adams' Report. One of them has in it small veins of white quartz (Fig. 272) which were filled, probably, by infiltration, the cracks having been made by the plication.

STRIKE AND DIP.

In the following observations no attempt was made to distinguish between cleavage and stratification. But we have presented considerations above which show that in the ranges east of the Green Mountains, the two are nearly or quite coincident; and in the few observations of a different character as to the western ranges, the difference appears to amount to only a few degrees.

The strike, as is usual with geologists, is given from the magnetic meridian, that is, by the compass. To convert it into angles made with the true meridian, it is only necessary to recollect that the declination of the needle in Vermont varies from 9° W., in the southwest part of the State, to 11° W., in the northeast part.

RANGE ALONG CONNECTICUT RIVER FROM GUILFORD TO EAST BURKE.

[The locality, strike and dip, and initials of the Observer are given.]

Near State Line, Bernardston, Mass., strike N. 70° E., dip 19° S., C. H. H. Southwest part of Vernon, strike N. 3° E., dip 63° E., C. H. H. Vernon, west part, strike N. 10° E., dip 70° E., C. H. H. Vernon, west part, strike N. and S., dip 25° E., C. B. A. Vernon, north part, strike N. and S., dip 70° W., C. B. A. Vernon, north part, strike N. 45° E., dip 50° N.W., C. H. H. Guilford, south part, strike N. 40° E., dip 80° S.E., C. B. A. Guilford, strike N. 5° E., dip 50° E., C. B. A. Guilford, strike N. 32° E., dip 48° E., C. B. A. Guilford, near Algiers, strike N. 5° E., dip 72 W., C. B. A. Guilford, New England Slate Co.'s quarry, strike N. 20° E., dip 77° W., C. H. H. Guilford, west of do., strike N. 20° E., dip 80° W., C. H. H. Chesterfield, N. H., strike N. 23° E., dip 85° W., C. H. H. Brattleboro, railroad depot, strike N.E. and S.W., dip 66° E., C. H. H. Brattleboro, west part of east village, dip 65° to 90° W., C. H. H. Brattleboro, near mouth of West River, strike east of north, dip 66° W., C. H. H. Brattleboro, northeast part, strike N. 30° E., dip 50° E., C. H. H. Brattleboro, northeast part, strike N. 25° E., dip 70° W., C. B. A. Brattleboro, south part, strike N. 33° W., dip 90°, C. B. A. Dummerston, south part, strike N. and S., dip 40° E., C. B. A. Dummerston, northeast part, strike N. 30° E., dip 78° E., C. B. A. Dummerston, north of railroad depot, dip 60° to 75° W., C. H. H. Dummerston, depot, strike N. 47° E., dip 35° to 50° E., C. H. H. Dummerston, east of village, strike N. 20° E., dip 45° to 75° E., C. H. H. Dummerston, center, strike N. 20° E., dip 51° E., C. H. H. Putney, railroad depot, dip 60° W., C. H. H. Putney, south part, strike N. 25° E., dip 56° E., C. B. A. Putney, north part, strike N. 25° E., dip C. B. A. Putney, north part, strike N. 25° E., dip 25° W., C. B. A. Westminster, southeast part, strike N. 30° E., dip 25° E., C. B. A. Westminster, northeast part, strike N. 47° E., dip 90°, C. B. A. Westminster, south part, dip 10° to 20° E., C. H. H. Westminster, north line, strike N. 20° E., dip 50° E., C. H. H. Bellows Falls, strike N. and S., dip 34° E., C. H. H. Rockingham, south part, dip 86° E. and 80° W., C. H. H. Rockingham, Saxton's River Village, strike N. 20° E., dip 68° E., C. H. H. Rockingham, center, dip 80° W. and 80° E. to 90°, C. H. H. Rockingham, on Connecticut River, strike N. 30° E., dip 85° W., C. H. H. Springfield, strike N. 5° E., dip 85° E., C. B. A. Springfield, strike N. 5° E., dip 75° W., C. B. A. Windsor, strike N. 10° E., dip 55° E., C. H. H. Windsor, on Connecticut River, strike N. 25° E., dip 43° E., C. H. H. Hartland, strike N. 20° E., dip 61° E., C. H. H. Mouth of Quechee River, strike N. 10° E., dip 55° E., C. H. H. Thetford Hill, strike N. 10° E., dip 85° E., A. D. H. Thetford Hill, east part, strike N. 24° E., dip 35° E., A. D. H. Thetford, slate quarry, strike, N. 20° E., dip 76° E., A. D. H. North Thetford, strike N. 35° E., dip 45° E., C. B. A. South Fairlee, strike N. 20° E., dip 45° E., C. B. A. Fairlee, Lain's quarry, strike N. 20° E., dip 45° E., A. D. H. Near do., strike N. 20° E., dip 35° E., A. D. H. Bradford, strike N. 28° E., dip 10° to 30° E., A. D. H. Newbury, strike N. 20° E., dip 65° E., C. H. H. Newbury, strike N. 10° E., dip 78° E., A. D. H. Newbury, strike N. 40° E., dip 76° W., A. D. H. Barnet, near Stevens Village, strike N. 40° E., dip 90°, C. H. H. Barnet, south part, strike N. 10° E., dip 85° E., C. B. A. Waterford, south part, strike N. 36° E., dip 80° E., C. B. A. Waterford, Hale & Brackett's quarry, strike N. 35° E., dip 80° to 85° E., A. D. H. Kirby, southeast corner, strike N. 35° E., dip 75° E., A. D. H. St. Johnsbury, east part, strike N. 30° E., dip 70° E., A. D. H. East Burke, strike N. 55° E., dip 54° E., C. H. H.

RANGE FROM BARNARD TO NEWPORT.

Barnard, north part, strike N. 3° E., dip 80° E., C. B. A. Bethel, strike few degrees east of north, dip 60° E., A. D. H. Braintree, strike N. and S., dip 90°, C. B. A. East Roxbury, strike N. 30° E., dip 75° W., C. H. H. Northfield, slate quarry, strike N. 28° E., dip 72° W., C. H. H. Montpelier, village, strike N. 30°–40° E., dip 70°–79° W., C. H. H. Montpelier, east part, strike N. 40° E., dip 70° W., A. D. H. Barre, strike east of north, dip 80° W., A. D. H. South Hardwick, strike N. 20° E., dip 85° E., C. H. H. Hardwick, west part, strike N. 20° E., dip 60° E., A. D. H. Craftsbury, strike N. 10°–30° E., dip 30°–40° E., S. R. H. Coventry Narrows, strike N. 40° E., dip 46° N.W., S. R. H. Coventry and Newport, strike N. 34° E., dip 75° W., C. H. H. Stanstead, C. E., strike N. 20° E., dip 68° W., C. H. H.

Average strike N. 24° E. — 10° = N. 14° E. Strike of formation, N. 13° E.

RANGE FROM TROY TO MORETOWN.

North Troy, strike N. and S., dip 65° E., C. H. H. Hydepark, strike N. 30° E., dip 90°, S. R. H. Morristown, strike N. 25° E., dip 85° W., S. R. H. Middlesex, dip 76° W., C. H. H.

The strike and dip of the clay slate, connected with the fossiliferous rocks along the west side of the State, are given in describing those rocks.

Range and Extent.

An inspection of the Geological Map will show that this rock occupies several narrow belts running through a large part of the State. They are not represented as entirely continuous, and we presume they are occasionally cut off entirely, or rather the slate is in some places converted into other rocks by metamorphic action. But we doubt not that they are more completely continuous than represented, because belts of rock so narrow cannot always be discovered by passing over a country half covered by drift and alluvium.

The most easterly range follows the Connecticut River as far north as Fairlee, where it seems to be arrested by an outburst of granite. No more is recognized till we reach the mouth of Passumpsic River. From thence it passes somewhat east of that river, till it seems to be cut off by the great masses of granite in the northeast part of the State.—Yet on the most northerly section Mr. Hall has placed in the east part of Holland, a stratum of novaculite which we know is usually associated with clay slate, and this may be the northern extremity of the Connecticut River range; though to reach that point in Holland, it must curve a good deal to the west.

The second range is represented as extending uninterruptedly from Barnard to Lake Memphremagog, and on the east side of the lake to Canada. South of Barnard it has not been noticed in sufficient quantity to find a place on the map. Its northern terminus on the map around Memphremagog, has not been traced out by us as accurately as it ought to be.

The third range commences in Troy and is quite narrow, passing often into plumbaginous slate or even into mica schist. It is probably pinched off in some places. But from having found this slate in small quantities as far south as Bridgewater, on all the sections we have ventured to represent a narrow continuous belt as far south as that town. We believe it has not been worked as roofing slate anywhere. As we have traced it out, it runs parallel most of the way to the second range above described, curving essentially as that does. South of Bridgewater we suspect that metamorphic action has changed this into some other rock. But on the two southern sections a slate appears which might well be called clay slate passing into mica schist. So that we doubt not this range was once continuous through the State.

In the talcose schist west of the Green Mountains, in the north part of this State, we have found at least one narrow belt of clay slate. We have represented it as extending only from Richford to Avery's Gore, although probably we might follow it further.—Another band exists still further west in Fairfield and Sheldon in connection with the talcose schist, and probably it extends further.

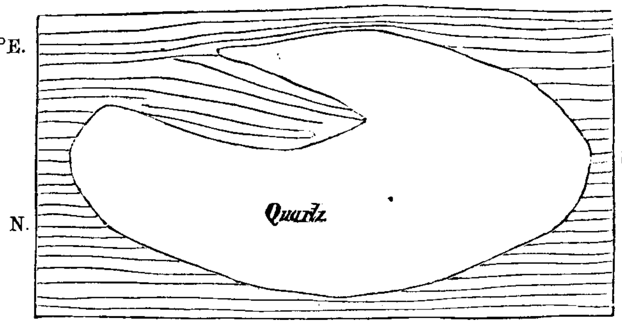
The principal belts of slate west of the mountains form constituents of what we suppose to be the Hudson River group and the Georgia group. Two belts are in the southern part of the State and two in the northern. The most eastern of the southern belt commences about as far north as Middlebury and runs to Arlington before it passes into New York. The western belt commences in Orwell and is separated from the western by a belt of limestone till the formation has extended a considerable distance into New York, where the two slate belts unite and the limestone disappears. The fine quarries of slate in western Vermont and in eastern New York occur in these two belts. The bands of slate in the northern part of the State extend in interstratified patches from the Winooski River to the Canada line. They ought rather to be called shales, and are not of a character to be employed in roofing.

Mineral Contents.

The simple minerals found in this rock are few. Where it passes into mica schist we not unfrequently find an imperfect sort of kyanite, (as at Bellows Falls) and garnet. Formerly novaculite would have been reckoned among the simple minerals; but it is obviously only a variety of the rock, and sometimes, as at Guilford, almost equal in quantity to the slate. It will probably some day become of economical value for hones, but as a mineral it possesses little interest.

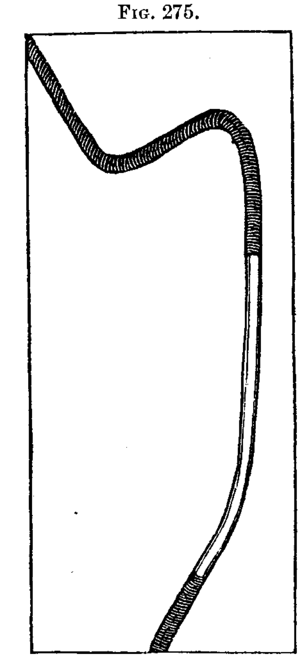
Quartz as a mineral is so common in all the rocks, that it is hardly worthy of notice, unless of peculiar varieties, or in great quantity. In the latter respect tubercular masses of white quartz, not uncommon in the clay slate, deserve to be mentioned. This quartz is nearly pure silex and is used in making the purest kinds of glass. It may be found in many places, especially where the clay slate is passing into mica schist. A mass occurs in the clay slate, or rather in the novaculite, near Bruce's quarry, in Guilford, of such extraordinary dimensions, and, moreover, of good quality, that it deserves a description. The sketch (Fig. 274) will render any further statements superfluous, except to say that this great quartzose boss occurs near the house of Edward F. Wilson, and is eight rods long and four rods wide.

Fig. 274.



The origin of such a huge mass of quartz is a very difficult problem in geology. It is the pure white quartz, not unfrequent in tubercular masses in the clay slate, and especially the schists of Vermont; but it is scarcely found in any of the unmetamorphosed rocks. Hence we are certain that it has undergone a change. We have already given our views of the nature of the change. In all cases where we find such pure white quartz, we believe that other ingredients have been abstracted from it by chemical agents, while the mass was in a plastic state. But what the original rock was in this case, is a more difficult question. Had the quartz formed an extensive interstratified mass, we might, perhaps, suppose it originally sandstone, which was converted, first into laminated quartz rock, such as occurs in Vernon and Bernardston, and then by the abstraction of impurities, into the pure white massive quartz. But it is a boss half as wide as it is long, having more the shape of a bed of steatite or limestone. Is it possible that it may have been limestone highly silicious, or which for a long time was permeated by water containing silica, by which the carbonate of lime was all abstracted? But since this quartz is the same variety which we meet with in the tubercular masses in many other parts of the clay slate, but few of which could have been limestone, perhaps the more plausible hypothesis is, that they are all the results of the decomposition of silicates in the wet way, which seems to have been the most usual origin of quartz rock.

Fig. 275.



Fossil in clay slate, Guilford.

FOSSIL.

The clay slate of Guilford has yielded us at least one undoubted fossil, shown on Fig. 275. It is a flattened cylinder, and by that character is distinguished from the trail of an annelid, which leaves only a furrow, with all the layers of the rock depressed. On the drawing a part of the stem is wanting, as it is on the specimen. It looks more like the stem of a coal plant than like the fucoids of the red sandrock. But we despair of being able to refer it to its true place on the scale of rocks.

Geological Position and Equivalency.

The clay slate west of the mountains forms one of the members of the Georgia group and the Hudson River group of the New York geologists, as is obvious by following the ledges on their line of strike southerly into N. York. Hence its geological age is the same.

The slate connected with the Georgia group, according to Sir William Logan, underlies the Quebec group, yet is not older than the Potsdam sandstone. Professor Hall has thrown some doubts upon this conclusion, by his reasoning upon the faunæ of the Quebec group. (*Amer. Jour. Sci., March*, 1861.) His previous opinion was, that the Georgia group was not older than the Hudson River group. The subject is in able hands, and will doubtless require much time and labor to settle it.

The age of the ranges east of the mountains is settled with even more difficulty, because the metamorphism is more thorough, and the age of the adjoining rocks is obscure. In order to find any fossils (so far as yet examined) in connection with the slate, we must pass out of Vermont into Canada on the north, and Massachusetts on the south, with the exception of the plant in Guilford, above described.

On the south we find the clay slate of Guilford extending a few miles into Bernardston, in Massachusetts. Here we find it associated with limestone, quartz rock, and magnetic iron ore; and the limestone contains encrinites. The position of these rocks may be seen on the section on Fig. 266, which has been already described.

Commencing at the S.E. we find a small knoll of distinct clay slate, with a strike N.E. and S.W., and a dip of 31° S.E., which are the strike and dip of all the other strata, excepting the obscure and disturbed conglomerate and slaty quartz immediately beneath the limestone whose strike and dip are uncertain. The quartzose conglomerate lying above the limestone is somewhat insulated from the other rocks, but the above is its probable relative position. The quartz rock lying immediately above the bed of limestone is very distinctly stratified, with some mica interlaminated, and often jointed. It extends northeasterly, into and through Vernon, but nowhere, save in Bernardston, have we found any slate lying above it. The great body of the slate, as the geological map shows, lies to the west and below the quartz. The semi-crystalline limestone is separated from the quartz by a thin bed of slate, and embraces a bed of magnetic iron, some of which has passed to the condition of limonite, not differing in appearance from bog ore. Only a few rods beyond the limestone northwesterly, we find a rock made up of fragments of quartz and slate, whose position is uncertain; but a little further is a slaty, dark colored quartz, apparently dipping northwest. Beyond this, at no great distance, we come to the clay slate, with a low dip, and as we proceed northwesterly we reach the great body of the clay slate with a higher dip and a strike upon an average considerably nearer the meridian. A little to the south and east of the limestone and quartz, the oolitic red sandstone, or more probably the new red or permian formation of the Connecticut valley covers the older rock with a westerly dip.

Now the limestone above described contains at least two species of encrinite, which Prof. James Hall thinks may belong to the period of the Onondaga limestone of New York, at least that they are not from an older rock. This rock is somewhere near the middle of the Devonian system. Assuming this to be correct and it will bring at least some of the Vermont clay slate into that system. The quantity of slate that lies above the limestone at Bernardston is indeed small, but sufficient to make it certain that at least a portion of this rock has that position, and is therefore not older probably than the Devonian age. The great mass of the slate does indeed lie below the limestone at Bernardston. But if the latter be the Onondaga limestone, there is still thickness enough in the Schoharie sandstone, Cauda galli grit and Oriskany sandstone of New York, to embrace all the Guilford clay slate, before getting as low as the upper Silurian, although it is not easy to see how clay slate could have been formed from these New York rocks.

The presumption then, is rather strong that the Connecticut River band of clay slate is of Devonian age. One cannot, however, but feel some doubts whether the Bernardston rocks are conformably stratified with the great body of slate, and whether we do not need more fossils, to speak with much confidence of the identification of the Bernardston with Onondaga limestone. But there is another spot, just without the limits of Vermont, in Canada, where stronger evidence is found of the Devonian character of the clay slate.—If the thirteenth of our sections be examined, as well as Figs. 267 and 268, we shall see on the west side of Lake Memphremagog, a bed of limestone interstratified with the slate, and that some of the slate, as in Bernardston, lies above the limestone. If we follow these rocks northerly into Canada, as far as Owl's Head, we shall find there several fossils, which palæontologists refer to the Devonian, and which have been described under Part II.—They doubtless could be found in the southern prolongation of the limestone in Vermont, but we have been unable to find the time necessary for a careful examination. The facts we have stated, however, make it probable that the second belt of clay slate, running from Memphremagog through the central part of Vermont, as far as Barnard, is of Devonian age. As to the third belt, further west, we have made no discoveries, but the presumption is that it is of the same age.

The relative position of the clay slate and the micaceous and talcose schists is well shown on the geological map and sections. On the map it will be seen that the two principal ranges of the slate form bands on the margins of the calciferous mica schist; and if the sections be consulted, it will be seen from the dip of the slate, that it lies above the schist in every case except on Section VII, where the slate on the west side of the schist in Bethel dips slightly under it. But this single exception, easily explicable either by supposing some local disturbance, or a folding of the strata, such as brought the schist uppermost, is not sufficient to disprove the conclusion from all the rest, that the slate is the newest rock. And who can doubt that it once mantled over the schist? If so, how enormous must have been the amount of erosion to form the present surface, as is shown on Sections VII, VIII, IX, and X, where the thickness of the upturned edges of the schist is 9, 13, 9½, 10½ miles, or average 10.5 miles. And when we look at these sections, especially at Nos. VIII, IX, and X, and see only a single anticlinal and no synclinal, it seems difficult to avoid the conclusion that we have only a single fold. Yet the enormous thickness that would thus be given to the strata—not less than 25000 feet—seems strongly to militate against such a view. Indeed the subject is one encumbered with difficulties.—But we have in another place given our views concerning it.

The position of the clay slate in respect to the talcose schist is also clearly seen on the sections. With one exception, on Section X, in Hardwick, it dips under the schist, though both the rocks are almost perpendicular. Consequently the talcose slate must be the newest rock, setting aside inversions. There seems no way to avoid this conclusion but by denying that the slaty and schistose structure correspond to the planes of stratification, or by resorting to faults and vertical shifts and inverted dips. Yet to admit that the talcose schist is newer than the clay slate, does not correspond with the conclusions that have been reached by following up the series of rocks from the Champlain valley, or with those of the eminent geologists who have charge of the Canada Survey. They make the talcose schists a part of their Quebec group, which they place at the bottom of the lower Silurian. But this is a most difficult subject, and the end is not yet. Our chief aim has been to present the facts without bias. We may have mistaken them, sometimes, but it has not been through the influence of any hypothesis, if we know ourselves.

The map will show that as the two easterly bands of clay slate approach the southern part of the State, they almost disappear and are replaced by more crystalline rocks, such as gneiss and hornblende and mica schist, with outbursts of syenite and granite. Our belief is that the metamorphism has been more intense in such places, and has converted the slate into the other rocks. In another place we shall endeavor to show that very much of the granite and syenite along the Connecticut valley has been formed by the melting down of conglomerate schists and slates. We have alluded already to a case where the slate, in the northeasterly part of the State, seems to abut against the granite. So in the southern part we find dikes of granite in the slate which have in them fragments of slate.

QUARTZ ROCK.

This rock has been so fully described under the fossiliferous group that it is hardly necessary to notice it again. The only reason for doing so is, that east of the mountains we have found in it no fossils. Yet, in the southeast corner of the State, or rather just within the limits of Massachusetts, at Bernardston, it is most distinctly and conformably superimposed upon limestone not older than the Devonian, as we have shown under clay slate. This deposit in Vernon has no great thickness, though greater in Bernardston. So in all other places east of the mountains, the beds of quartz are generally but a few feet thick. They are interstratified with talcose schist and gneiss, as indeed the quartz is on the west side of the mountains. Generally the quartz in these more crystalline rocks seems to have undergone a more thorough metamorphosis, so as to become frequently hyaline. The white tubercular masses of quartz not uncommon in clay slate and mica schist, seem to have been for some reason more free from iron than the granular and more colored varieties west of the mountains. But this subject has already been treated of under metamorphism and elsewhere.

The geological associations of many of the beds of azoic quartz may be seen upon our sections, though we have attempted no distinction between the fossiliferous and azoic varieties. The lithological characters of all the varieties can be learnt only by consulting the specimens in the State Cabinet. In this place we propose only to present our views of the geological position, equivalency and origin of all the quartz rock of the State. We first give, however, a list of the dips and strikes of quartz rock in Vernon, Bernardston, and Plymouth.

DIP AND STRIKE OF QUARTZ ROCK — OF TWO RANGES IN EASTERN VERMONT.

[The locality, strike and dip, and initials of the Observer are given.]

North Vernon, strike N. 14° E., dip 25° E., C. H. H. North Vernon, strike N. 10° E., dip 30°–35° E., C. H. H. Vernon, north of hotel, strike N. 10° E., dip 40° E., C. H. H. Vernon, glass sand locality, strike N. 10° W., dip 40° E., A. D. H. and C. H. H. Vernon, southwest part, strike N. 30° E., dip 70° E., C. H. H. Vernon, southeast part, strike N. 60° E., dip 35° S.E., C. H. H. Northfield, Mass., near Vermont line, dip 30° E., C. H. H. Bernardston, Mass., east part, strike N. 55° E., dip 10°–12° E., C. H. H. Bernardston, near the limestone, strike N. 65° E., dip 29° E., C. H. H. Bernardston, near the limestone, strike N. 50° E., dip 25° E., C. H. H. Bernardston, near the limestone, strike N. 60° E., dip 52° E., C. H. H. Bernardston, north of limestone, dip 60° W., C. H. H. Plymouth, north part, dip about 20° E., C. H. H. Plymouth, average of range, strike N. 10° E., dip 40°–50° E., A. D. H. Plymouth, north part, strike N. 10° W., A. D. H.

Geological Position, Origin, and Equivalency of Quartz Rock.

Quartz rock has a very large development in Vermont, as the geological map and sections will show. But its position relative to other rocks, its geological age, origin and metamorphism, have perplexed us very much. Where it occurs in thin beds, interstratified with other rocks, as it often does in Vermont, its position is fixed. But in those immense masses that lie along the western side of the Green Mountains the stratification is often obscure, and the joints are easily mistaken for it. We think, however, that there can be no doubt but that the quartz rock has a conformable stratification with the associated rocks, that is, along the west side of the mountain, a large easterly dip, or sometimes a vertical position.

As we pass along the west base of the Green Mountain range from the southwest corner of Massachusetts, as far north as the Winooski River, nearly 170 miles, we have on our right a steep wall of micaceous and gneissoid rock, from 1500 to 2000 feet high, without a break in it till we reach the Winooski; and to the east of the mountain crystalline rocks extend across the State—nay, to the coast. But west of us limestones, quartz rock and slates prevail, being in general less crystalline, and at length disclosing fossils. The west base of that mountain range seems to be a dividing line between the crystalline rocks on the east and those less metamorphosed on the west. Moreover, along this valley it seems as if the strata had been sharply crowded together, so as to form a synclinal axis by a force from the southeast, as if the whole body of the Green Mountains had been crowded against the strata to the west, causing them also to assume an easterly dip, which, however, becomes less and less as we go westerly, just as might be expected if thus produced. That the strata of the Apalachian range have been folded by a force from the southeast, seems now generally admitted. Along the line we have indicated, there seems to have been one of the synclinal folds. The facts we have detailed respecting the conglomerate of Wallingford and Plymouth make it probable that the crest of the Green Mountains is an anticlinal fold. Yet the movement towards the northwest has caused the strata to fall over, so that almost everywhere the dip is southeasterly. The strata east of the mountain have been crowded into other folds, as our sections show, and as we have elsewhere pointed out. There have been foldings, also, west of the mountain, but they seem to have been less extensive. There a general movement has taken place, partly we think by the lateral plication above described, and possibly by some upheaving force exerted by the mountains of northern New York, and the result is a moderate and more uniform elevation.

As already intimated, along this same synclinal line at the west foot of the mountain, we think there was a change of metamorphic action. To the east it was powerful and all-pervading, obliterating fossils, and bringing in crystallization and other superinduced structures. To the west, it did indeed convert immense masses of calcareous matter into white crystalline limestone, but the associated talcose and micaceous schists have much less of a crystalline aspect, and are less distinctly foliated, while the feldspars are hardly developed at all, and ere long the clay slate and its associated limestones begin to exhibit fossils. The rocks generally at the west of the synclinal line have a more earthy aspect than to the east of it.

Now it is along this synclinal that the chief development of quartz rock occurs, both in Massachusetts and Vermont, and we might say the same of the belt of similar rocks stretching southwesterly to Alabama. And if it occupy, as we have supposed, the bottom of a synclinal trough, rising on the one hand upon the side of the Green Mountains, and on the other upon the Taconic range, then it may be the newest of all the rocks of western Vermont. All agree that as we go eastward from Lake Champlain, for a time at least, we pass over newer and newer rocks. But when we reach the crystalline limestone and the quartz rock, which lie near the Green Mountains, it has been generally supposed that these must be at least as old as the Potsdam sandstone. Our most recent discoveries, however, have been leading us to the conclusion that these rocks are as high in the scale as the upper Silurian, if not in the Devonian. Of the limestone, we have already presented some suggestions; but the only fossils hitherto found in the quartz rock, are the Scolithus—a supposed marine plant, and a species of Lingula. The former is abundant in Bennington and Sunderland, as well as in Adams, in Massachusetts: but it does not decide what the formation is. The latter, though found many years ago by Henry Miles, of Monkton, has only in the autumn of 1860 been put into our hands, by his kindness. Prof. James Hall has examined it, and says: "The Lingula, though unsatisfactory, I regard as evidence of rocks of the age of the Clinton group of New York, or of Medina sandstone—a position reached by sandstones, a part of which we include in the Clinton, and a part in the Medina sandstone." We incline to the opinion that this main belt of quartz rock is at least as new as the Medina sandstone, and should it turn out that the Eolian limestone is as new as the Devonian group, possibly the quartz rock may also belong there. At any rate we have doubts whether the old opinion, that it is as old as the Potsdam sandstone, can be maintained.

On the supposition which makes the quartz rock and Eolian limestone very low in the series, it was necessary to explain the facts to suppose faults to exist, and uplifts and downthrows to have been made, where there is no evidence of such phenomena; or if these suppositions would not account for the facts, resort must be had to metamorphism. By these means a geologist can prove anything he pleases in relation to the position of rocks. But when he tells us that in such a place is a fault, or an uplift, or a downthrow, we are not disposed to admit it without evidence, merely because it is necessary to sustain his hypothesis. We have seen proof of such changes in the rocks of Vermont in many places; but our sections show that they have not all been inverted and dislocated.

By reference to our description of the remarkable conglomerate of Wallingford and Plymouth, and to our Sections, it will be seen that the quartz rock at Wallingford lies above the conglomerate, although the dip of both rocks is near 90°. That conglomerate we have been inclined, from its lithological characters, to refer to the Oneida conglomerate or Shawangunk grit, of New York. This lies immediately below the Medina sandstone, from the metamorphosis of which the quartz rock may have resulted. There can hardly be any doubt that the conglomerate once mantled over the mountain, as represented on

Fig. 18. If so, probably it was overlaid by the quartz rock. Indeed, we find the quartz in the vicinity of the conglomerate in Plymouth, where, as in Wallingford, it is associated with brown hematite. Yet most of the quartz is wanting in Plymouth, except some beds below the conglomerate. Whether denudation has swept it away (which is most probable, judging from the amount of quartz bowlders strewed through the valley), or whether metamorphism has here converted the sandstone into schist, as is quite possible, we will not attempt to decide. Yet having been led by one class of evidence, chiefly palæontological, to refer the quartz rock to the Medina sandstone, and by another class to refer the conglomerate to the Oneida conglomerate, their juxtaposition and superposition rather strengthen the presumption that such was their origin.

It ought to be remarked, that if it be admitted that the principal deposit of quartz rock along the western side of the mountain, may be metamorphosed Medina sandstone, it does not follow that the numerous beds of quartz interstratified with the schists and gneiss in other parts of the State, are of the same age. They may be of different ages in different places, and have experienced different degrees of change. Some of these quartz beds are white as snow; others are gray, but almost hyaline; both are often very pure, the ingredients once associated with them having been abstracted, perhaps in the manner we have endeavored to indicate in our remarks upon metamorphism.

It happens, however, that there is one deposit of quartz rock, of no great thickness, in the southeast corner of the State, in Vernon, whose geological age we can, with some probability, fix upon. To do this, we must follow the rock on the line of strike southwesterly into Bernardston, in Massachusetts. There we find it dipping at a small angle, and overlying a bed of limestone, which abounds with encrinites. We have already, in our description of clay slate, given the details of this case, and stated Prof. Hall's opinion, that the age of this limestone cannot be older than the Onondaga limestone of the Devonian group. The quartz rock lying above it is probably about of the same age.

According to these views we start with the oldest of the Silurian rocks on the west side of the State, and end with the Devonian on the east side. But it does not follow that there is an uninterrupted succession of newer and newer formations on the way. For we have no doubt, as we have endeavored to show in another place, that the rocks are arranged in several anticlinal and synclinal folds, whose higher parts have been deeply denuded, and thus older strata, we know not how old, have been exposed, so that in crossing the State we may pass over rocks of various ages. Our impression, upon the whole, is, that the several bands of clay slate may mark out layers as high as the upper part of the upper Silurian or even Devonian strata. The band along Connecticut River may indicate the second or third replication.

We have been led to these suggestions (they hardly deserve the name of regular conclusions) by the facts that have been detailed. But as they do not accord with any of the various views that have been offered by eminent geologists, we do not expect that they will receive much consideration. We do not offer them with any ambition to propose any new hypothesis respecting these difficult phenomena, nor in the expectation that they afford a complete explanation of the phenomena; but only in the hope of making a little advance into the region of the doubtful and unknown. Long as we have been in the geological field we have never taken any decided ground on this subject; nor, indeed, have had decided opinions concerning it, although our writings have sometimes been quoted to prove that we were even partizans in the warfare. Especially have we been charged with hostility to the Taconic system of Prof. Emmons. But we have never been conscious of such a feeling. Nay, if the fundamental principle of his system is that there is a system of rocks below the Silurian containing peculiar fossils, we fully admit it. For how does this differ from the Cambrian system of Great Britain, or the Huronian system of Sir William Logan, or the analogous systems of Bohemia and Scandinavia?—and these may be considered as established. We are not, indeed, convinced that any of the rocks of Vermont belong to the Taconic system. But if our old friend Prof. Emmons shall be able to prove that they do, we shall rejoice in such a result to his indefatigable efforts. We have taken pains, in another place, to give a full view of his system as we have of the discussions now going on among eminent geologists and palæontologists respecting the rocks of western Vermont and Canada. We believe that much remains yet to be done in this field before all the important questions shall be settled, and we hope that discussions on such a subject may be conducted with candor and without personalities.

The origin of quartz in the various forms in which it occurs in the rocks, raises questions of much difficulty with the chemical geologist. In its pure state it is composed of silex. Now silex exists in two states. In one state it is insoluble in water and most acids, except the hydrofluoric, which seems never to have been concerned in geological changes. All the forms of common quartz belong to this variety of silex. But there is another form of this substance, when it is soluble in water and acids, and in fact "is present in all water," according to Bischof. Its largest amount in cold springs is $\frac{1}{10000}$th part. It occurs also in solid state, either as a powder, or gelatinous from the decomposition of silicates.

Quartz occurs in several forms. 1. As thick deposits on beds interstratified with other rocks, either in a hyaline, milky, or granular state. These masses in Vermont are hundreds, not to say thousands of feet thick. 2. As veins or dykes. 3. As a constituent of rocks. 4. In drusy cavities. 5. As cemented sand in sandstones. Let us see in what modes these several forms may have been produced.

1. It might be deposited from solution in water, from hot water especially, such as the Geysers or hot springs. In that way quartz veins and drusy cavities may have been filled. It is possible, also, in this way to account for extensive deposits. A pound of hay growing upon three square feet of soil, abstracts from the soil, by means of water, $\frac{1}{150}$th of a pound of silex. If this were deposited by the water at that rate per year, it would, in 78,705 years, form a layer one foot thick. Hence, as geology always has time enough at command, deposits of quartz of any thickness could in this way be formed.

2. By the decomposition of silicates. Such decompositions may be effected in water holding silicates in solution, by the action of free carbonic acid, or by organic substances, which produce by putrefaction carbonate of ammonia, and this precipitates both silica and alumina. In view of these and other facts, Bischof makes the sweeping assertion, which, it seems to us, should be somewhat modified, that "Quartz appears in all cases to be a product of the decomposition of silicates in the wet way." (*Chemical and Physical Geology*, Vol. II, p. 479.) Such an origin agrees best with the character and arrangement of quartz in granite, syenite, and some varieties of gneiss; but we have seen that deposition from solution in water has given rise to some varieties. Yet, perhaps Bischof would say that the silex held in solution by water was the result of the decomposition of silicates. In that sense his proposition might be true as to the origin of quartz. But we are endeavoring to point out its state immediately preceding that in which we now find it.

3. By the abstraction of soluble silicates. We refer here to those cases where highly silicious masses, such as pebbles, have been permeated by alkaline water, and this has dissolved out and removed the silicates, leaving the excess of silica in the form of white or hyaline quartz. We have given our reasons for believing that such an abstraction has taken place in certain conglomerates, and the tertiary coal, and we strongly suspect that it has extended to most of the cases where tubercular masses of quartz in the schists exhibit great purity.

4. By the conversion of limestone into quartz rock. The process is well described by Bischof: "Supposing a bed of limestone, uniformly permeated by water, containing silica, during a long period, nothing is easier to conceive than that, by the removal of carbonate of lime and the substitution of silica in its place, the whole rock would ultimately be converted into a quartzose mass." This process might stop at any point of the metamorphosis, and the result might be silicified rocks containing more or less of carbonate of lime, which are often called silicious limestones. This case is well illustrated by what is called the red rock in Vermont, which, near Burlington, produces the beautiful Winooski marble.

5. By the conversion of sandstones into quartz rock. If the sandstone consist of grains of pure quartz, which is rarely the case, its permeation by water holding silex in solution might furnish a silicious cement, so that the rock would become granular quartz. But if the sandstone comes from rocks containing more or less of silicates, and these be penetrated by water with alkalies, the result would be an abstraction of the soluble silicates, leaving the excess of silex as quartz. We are inclined to believe that this may be one of the modes in which extensive quartz formations have originated.

To account for the varied forms of quartz in the rocks of Vermont we think we must call in most of the preceding modes of its production. Its most usual origin, however, is as a residuum in the processes of metamorphism. Any attempt to derive it from igneous fusion appears improbable, because of all substances it is one of the most infusible.

TALCOSE SCHIST.

We describe this rock as a formation including, besides the lithological talcose schist and its varieties, the associated belts of rocks of different structure. The three ranges of it combined cover perhaps a larger area of the State than any other group of rocks.

We shall not include steatite or soapstone in this formation; first, because it is not confined to the talcose schist although most common here; secondly, because it now appears that there is scarcely any more affinity between steatite and talcose schist than between it and mica schist or gneiss.

Lithological Characters, with interstratified rocks and veins.

Talcose schist proper consists of quartz and talc. But in consequence of the researches of chemists our views respecting the composition of talcose schist have undergone an important change. To make this understood, we shall introduce as a preliminary a paper read by the Chemist of the Survey at the meeting of the American Association for the advancement of Science, at the Springfield Meeting, "On the so-called talcose schist of Vermont," in 1859.

ON THE SO-CALLED TALCOSE SCHIST OF VERMONT.

The geological surveys of the various States, have made known to us the existence of a broad belt of rocks, extending from Canada to Alabama, consisting of green schists, associated with gneiss and gneissoid rocks. The green schists have been denominated *talcose*, both in New England and further south. In our remarks, however, we would not be understood to affirm a non-magnesian character to any of these rocks south of Massachusetts, because we have not examined them. At the same time there is a strong probability that their mineralogical characters are the same; unless, perhaps, the disagreement existing as to their age be full proof of their difference in composition. For the Canada Survey presume them to be metamorphic rocks of lower Silurian age, while the Pennsylvania Survey regard them as hypozoic. First of all observers in this country to our knowledge, Mr. T. S. Hunt, of Montreal, has stated that certain rocks of this belt at its northern prolongation, which would be regarded by most observers as a highly talcose schist, are almost destitute of magnesia, alumina being present in a large per cent. in its stead. An analysis of one of these schists from St. Marie gave

Silica, ...	66.70
Alumina, . . .	16.20
Peroxyd of iron, . .	6.90
Lime, ...	.67
Magnesia, . . .	2.75
Alkalies (by difference), .	3.68
Water, ...	3.10
	100.00

Upon the Chaudiére River, near Quebec, Mr. Hunt found specimens of pholerite in the crevices of the ledges, whose composition was about forty-six per cent. silica, thirty-eight per cent. alumina, and fourteen per cent. of water. To pholerite and pyrophyllite, both hydrated silicates of alumina and quartz, Mr. Hunt has referred the composition of the so-called talcose schists.

The same gentleman found that the clay slates or roofing slates in the vicinity of these talcose schists had essentially the same composition as the latter, excepting that they contained a larger percentage of alkalies, but never more than seven or eight per cent; the talcose schist that he analyzed giving nearly three per cent. by difference. Hence he supposes that the talcose schists are formed from the clay slates by metamorphism.

He supposes that the mineral pholerite has been in a state of solution, "produced during the decomposition of the clay slates, which are made up to a large extent of the veins of feldspathic rocks. These slates are slowly giving up their alkalies to infiltrating waters, and are thus being converted into kaolin. He adds, "A great portion of the talcose slates of the Alleghany range, especially those associated with the gold deposits, throughout the eastern part of North America, are derived from the alteration of clay slates, and must be aluminous in their composition. It will be well for the future, to distinguish them, on account of their luster, by the name of *nacreous slates* or *nacreous schists*."

These observations induced us to examine the same rocks, as they occur in Vermont, in a more highly metamorphic condition, and to ascertain whether their character is magnesian or aluminous. We selected specimens from four different localities; such specimens as were apparently the best characterized talcose schists in the State. The results agree with those of Mr. Hunt. The analyses were kindly performed by Mr. G. F. Barker, B. Ph., of Boston, a careful chemist, who has given the following account of them:

"*Talcose Schist* (so-called), Roxbury. This rock is schistose, friable, of a greenish-gray color, fissile; sp. gr. 2.72. The analysis gives the following result:

Silica, ...	69.90
Alumina, and peroxyd of iron,	20.00
Lime, ...	1.51
Magnesia, ...	1.80
Soda, ...	2.33
Potassa, ...	1.45
Loss by ignition, ...	2.40
	99.39

"From the analysis it will appear evident, that the name talcose applied to this rock is a misnomer; there can be neither talc nor chlorite in them, for both these contain from thirty-two to thirty-six per cent. of magnesia. Mr. Hunt has proposed the name of nacreous slates, from their luster; the small proportion of water in this rock would seem to indicate some other mineral than pyrophyllite, and the total absence of any exfoliation under the blowpipe would tend to confirm this impression."

We would say of the position of the specimen analyzed, that it is from the middle of the talcose schist formation, and is from the vicinity of a bed of verd-antique serpentine, which is decidedly magnesian in its character. We selected this specimen as the most likely of any in the whole State to contain magnesia.

"*Talcose Schist*, from Pownal. This is another schist of the same general character as the preceding. Its color is bluish-gray; not as friable, but its feel is more unctuous. In dissolving the fusion with carbonate of soda in hydrochloric acid, hydrosulphuric gas was evolved, which blackened a solution of acetate of lead; yet the mineral, when treated with strong nitric acid and boiled, gave no reaction for sulphuric acid, as would be the case had there been sulphurets present. The analysis was as follows:

		Oxygen.	
Silica, ...	42.90	22.73	
Alumina, and peroxyd of iron,	42.20	19.71	
Lime, ...	.78	.22	7.22
Magnesia, ...	1.98	.79	
Potassa, ...	5.24	.89	
Soda, ...	1.33	.34	
Loss by ignition, . . .	5.60	4.98	
	100.03		

That this is a distinct rock from the last, is shown by the differences in the silica and alumina, there being twenty-seven per cent. less of silica, and twenty-two per cent. more of alumina. The specific gravity is greater, being 2.90; the magnesia remains nearly the same, while the alkalies and water have doubled. An analysis of talcite (Dana's Mineralogy, 4th ed. p. 509), by Tennant, strikingly agrees with this in composition. The specimen used was from Wicklow, Ireland (Cambrian.) The oxygen ratios in this specimen will be seen to be nearly 1 : 3 : 3 (that is 1 : 2.7 : 3.14) giving the formula $(RO, R_2O_3) Si.O_3$ ... ..

The specimen analyzed is an ordinary sample of a somewhat decomposing schist, which is called *magnesian slate* by Prof. Emmons. It is one of the members of the Taconic System, which in this Report we describe as talcoid schist. Pownal is upon the classic ground of this system of rocks, and there can be no doubt that this specimen was taken from the true magnesian slate of that system.

"*Talcose Schist*, Middlesex. This is another of the so-called talcose schists, perhaps more properly *talcoid*. It is less schistose and more slaty than the preceding specimens; color olive-green; odor argillaceous; composition,

Silica, ...	64.10
Alumina and peroxyd of iron,	23.50
Lime, ...	.84
Magnesia, ...	1.98
Potassa, ...	3.70
Soda, ...	2.20
Loss by ignition, . . .	3.60
	99.92

"This resembles more closely the analysis of the Roxbury specimen, the silica being a little less and the alumina a little more than in that rock. The proportion of the composing mineral varies, being mixed with extraneous matter. Scattering through it are octahedral crystals of magnetic oxyd of iron. These were carefully removed by the magnet from the portion of the rocks submitted to analysis. The presence of these rendered the determination of the specific gravity inaccurate. It is less friable than the preceding; has more tenacity; before the blowpipe it is unaltered; a thin sliver, however, being softened on the edges."

The geological position of this specimen is at the eastern part of the formation; and is probably not far from the base. The rock is intermediate in character between clay slate and talcose schist.

"*Novaculite,* Irasburgh. This is a mineral, very homogeneous in composition, fracture rough, structure amorphous, translucent, of a dirty gray color, streak white, specific gravity 2.65. A careful analysis gave the following composition:

		Oxygen.	
Silica,	78.70		
Alumina,	12.80		
Peroxyd of iron,	trace.		
Lime,	1.23	.35	
Magnesia,	traces.		1.94
Potassa,	.89	.15	
Soda,	5.57	1.44	
Loss by ignition,	.60		
	99.79		

"This would make the oxygen ratio, 1:3:21, or $(RO, R_2O_3)\ 7SiO_3$.

"Though called on the label talcose schist, its physical and chemical characters are widely different. Of magnesia there is but a trace, and the loss by ignition is small. Before the blowpipe it becomes white and opaque, is infusible, and colored the flame-yellow; with cobalt solution it gives a fine blue."

This is the most unctuous of all the specimens analyzed, and according to this supposed criterion for the presence of magnesia, a large per cent. is indicated. A rock of this character is very common in the talcose schist formation, and in the catalogue of the Vermont State Cabinet it receives the name of novaculite schist. It is also abundant in the Georgia group of slates.

Observing that upon the Canada geological map (in manuscript) the same color was given to the red sandrock about Burlington, Vt., and to the talcose schist formation (which they call lower Silurian), we were led to desire a chemical examination of the red sandrock. A specimen which had rather more silica than common was used, with the following result; analyzed by Mr. Barker:

"A hard, compact sandrock; specific gravity, 2.65; color, dark red,—on ignition it changed color, becoming blacker; composition:

Silica,	83.30
Alumina and peroxyd of iron,	8.70
Lime,	1.12
Magnesia,	.10
Potassa,	4.59
Soda,	.45
Loss by ignition,	.80
	99.06

"The excess of silica is due to sand present. It could not be separated, as the rock is not decomposable by acids. The oxygen ratio of the basis is 1:3."

With the exception of the excess of silica, which is only occasional, both in the red sandrock and talcose schist, the proportions of the other components agree. Hence it is not unlikely that the sandrock may be altered into talcose schist; so that we may have two sources for the schist, from clay slate and sandstone.

There is another consideration connected with this subject, of great importance. Associated with the schists is gneiss. The two rocks pass into each other by degrees. For instance, the belt of aluminous

schists in the northern part of Vermont is several times as wide as the same formation in Southern Vermont; but by including two belts of gneiss with the talcose schists in the southern part, the whole width corresponds to that in the northern part. In southern Massachusetts, the same belt of talcose schist entirely disappears, to be replaced by gneiss; but again in Connecticut, we believe, the talcose schist reappears. Thus a rock disappears and reappears while the strata have the same dip and strike, and we can discover no line of demarkation between them. By recurring to the analysis, we find that the composition of all of them correspond with that of the gneiss also — for the principal constituents are silica, alumina and alkalies — and the latter is as largely developed in the schist as in several analyses of gneiss that we have consulted. Hence then we have another stage of metamorphism: first there is a simple sediment — if coarse, it is sandstone; if fine, clay slate. A change takes place called metamorphism — the effect of heat and water combined — which converts these sediments into nacreous or aluminous schists. The continued and probably intensified action of the same causes converts these schists into gneiss, or feldspathic rocks. And were we to imagine a still greater increase of temperature, this gneiss might melt into granite—thus the whole process of the strongest metamorphosis would be seen. If this is so, it is possible that we have instances of the last stage of the metamorphosis in occasional hills of granite in the talcose schist formation, as in the towns of Bridgewater and Braintree in Vermont, and in the gneiss of the Green Mountains in the towns of Stamford, Sunderland, Stratton, etc. The talcose schist formation which we have been describing lies upon both sides of the principal range of the Green Mountains, especially upon the east side. But the Green Mountain range itself — in Massachusetts forming Hoosac range, and in Vermont extending through the State — is composed of gneiss and gneissoid rocks. In northern Vermont, in the range of Mansfield Mountain and Jay Peak, it becomes more talcose, but with shining crystals of feldspar appearing in the edges of the strata. We never should have regarded this rock in northern Vermont other than talcose did we not examine the formation along its axis and notice the gradual change into talcose schist with crystals of feldspar. In several localities in this vicinity this rock may be called a talcose sandstone, whose sedimentary character has nearly disappeared in consequence of the metamorphic action. Thus in this principal range of the Green Mountains may we see another example of the change of talcose schist to gneiss.

We say *talcose schist* for two reasons: the universality of the non-magnesian character of this rock, though probable, ought not to be considered as settled by five analyses. Almost every stratum of this rock presents some variation from the adjacent ones. It may be that a large number of these may yet be found to be magnesian, while many are aluminous. If so and it should appear at some future day, it would be much better for the cause of science that we retain the old name, talcose, for the present, and at the same time express the conviction that probably there is no magnesia present in any of it. Such a scientific conservatism is always safe. And, secondly, the analysis of some of these specimens shows that they agree with the mineral *talcite.* Hence it will be perfectly proper to use the name *talcite schist,* or its congener, *talcose schist.* For these two reasons, then, we think that it would be well to retain the old name for the present.

After discovering that magnesia in talcose schist was unfrequent, among our metamorphic rocks, the inquiry arose, how is it with talcose schist in other localities—does it contain magnesia or not? Mr. Barker referred to four analyses of talcose schist from Bischof (Bischof's Geology, Cavendish Soc. ed., p. 352), three of which agree essentially with the Vermont specimens, but the fourth contained 26 parts of magnesia. The non-magnesian specimens were from Sweden, Germany, and Tyrol; the magnesian example from Austria.

Bischof adds this note: "What is often called *talcose* slate contains none or merely traces of magnesia, as analyses I, II, III, show."

Thus there are two great varieties of talcose schist in Europe, one of them corresponding to the aluminous schist in New England. Whether any true magnesian slate from this country has ever been analyzed, we are unable to say.

NOTE. In a letter from Mr. T. S. Hunt, written since the reading of the preceding article, several suggestions are made which deserve to be mentioned, and therefore I add an extract from it:

"I did not hear your paper on talcose schists, and do not know but you have compared your results of the so-called magnesian slate with a small amount of silica and much potassa, with the *dysyntribite* of Professor Shepard, which forms beds in the Laurentian rocks of Northern New York, and resembles serpentine. You will find analysis by Brush in Silliman's Journal, second series, Vol. XXVI, p. 68, as also analyses of what I call *parophite*. It is a shale of the Hudson River group, locally altered by trap, and changed into what seemed a serpentine, whence the name. In Brush's paper, analysis 3, p. 68, is of the unaltered earthy shale, which further on passes into a green, translucent, unctuous mineral—analyses 1 and 2. (See also my Report, as cited by Brush.) We can scarcely doubt that the mineral from the Laurentian of Northern New York, where the same matter occurs crystallized as *gieseckite* (see Brush), is identical with you rmagnesian slate and my parophite and unaltered shale — since they agree in their peculiar composition, so different from ordinary shales and slates. These matters I regard as perhaps a sort of kaolin which has fixed a portion of the potash."

I learn, also, from Mr. Hunt, that he has found specimens of real talcose (magnesian) schist among the group of rocks now under discussion. It seems, then, that a protracted, minute, chemical examination is yet needed before the members of this group of rocks can be satisfactorily named.

We will describe the varieties belonging to this formation under two heads; first, the varieties of talcose schist; and secondly, the characters of all the associated or interstratified rocks except serpentine, steatite and azoic limestone.

1. *Schistose Talc.* This variety is more or less distinctly foliated, and varies in color from blackish-green to very light green or greenish-white. It is the least abundant of any of the varieties.

2. *Steatite.* This is properly a variety of this formation, but as it occurs in considerable quantities, and is of great consequence, both theoretically and economically, we describe it and all its varieties under a distinct head.

3. *Chlorite Schist.* Sometimes this variety is foliated, and of a dark-green color; and in such cases it is distinguished from talc externally, chiefly by its darker color. In composition chlorite is a hydrous silicate of alumina and magnesia, while talc is a hydrous silicate of magnesia. In structure it approaches what in popular language is called slate. In this case it probably owes its slaty structure to a small proportion of quartz which it contains. Belts of this variety are quite common. For instance, in the west part of Berkshire, running down to Essex, and perhaps to the extreme south end of the west range; another, running north through the east part of Hydepark; and a third, parallel to this, in the east part of Wolcott. Other local deposits are noticed upon the catalogue, e. g., in the towns of Johnson, east part, Granby, Middlesex, west part, and Bethel.

4. *Serpentine.* This, like the steatite, is of so much consequence that we describe it under a separate head.

5. *Quartz and Talc.* This is the variety in which magnesia is really present. The talc is usually scaly, and the quartz arenaceous. Sometimes, however, the latter is coarsely granular or hyaline. But it is with great difficulty that any distinction can be drawn between this and the following variety. We know of no means of distinguishing the two except by chemical analysis. And the real magnesian schist seems to be the least common of the two.

6. *Talcite (?) and Quartz.* By this term we include the non-magnesian schists. Regarding it as the common rock of the formation, we will mention some of its minor varieties. Of these there are two general kinds: those with a very unctuous feel, and those that are harsh and rough, though scarcely differing in appearance from the softer specimens. There is first a fine-grained, light green colored, rather slaty rock, very soft, so that thin specimens can easily be picked into pieces by the fingers, and exceedingly unctuous. There is an immense amount of this rock in the eastern part of the middle range in the northern half of the State. Associated with it in alternate layers is a rock distinguishable from it only by superior hardness. Then there is a compact schist, with quite evenly separated layers, of an average thickness of less than an inch, rather fine-grained, but less unctuous. This terminates in a real slate, such as can be distinguished from clay slate only by the absence of the argillaceous odor. A fine locality of this, and of its junction

with clay slate, may be seen a few rods east of the State House in Montpelier, at a Catholic church. North of the State House may be seen another very common variety. The ledge is compact, with few traces of stratification, like ledges of serpentine, and the rock is very coarse grained: being apparently composed of coarse unctuous crystals of the nacreous mineral constituting much of the rock. In other cases, like the specimen analyzed from Roxbury, the feel is somewhat unctuous, and very fine crystals appear elongated like delicate forms of hornblende. But of these unctuous varieties there is an endless variety. Most of the specimens upon the sections of this formation might profitably be described thus minutely.

Of the harsher variety there is a great amount. Every grade from soft nacreous schist to sandstone may be found. Generally it differs from the other varieties only by its roughness, and there is a corresponding variety in its texture. Certainly this is not talcose schist, because the essential characteristic of that rock, the softness, is wanting. But we have proposed no new name for it, calling it gritty talcose schist, talcose grit, or perhaps the term used for an analogous rock, talcose quartz rock. All these names are erroneous: but in the present state of our knowledge an error will be conveyed by their provisional use.

To show the nature of this formation we will present a list of the different varieties passed over between the clay slate in Montpelier, and the gneiss in Duxbury, along Winooski River. This section crosses the principal range, and was the most carefully measured of all the sections. Every ledge was examined along a region where they were unusually numerous. Although there is no evidence of a fold in this section, we suppose one to exist there, and hence the rocks are repeated. But we are unable to draw the exact line, and therefore mention the character of the successive layers over the whole section, commencing at its eastern boundary, following the clay slate.

Talcose slate, cleavage like roofing slate.
Common talcose schist, slightly unctuous.
Very soft coarse grained talcose schist (north of State House.)
Gritty talcose schist.
Compact bright green talcose schist.
Gritty talcose schist.
Talcose conglomerate, with a few crystals of feldspar.
Soft unctuous talcose schist.
Talcose sandstone.
Stratum of quartz (six inches.)
Decomposing gritty talcose schist.
Compact talcose schist (altered sandstone.)
Gritty talcose schist.
Ordinary talcose schist, slightly unctuous
Compact talcose sandstone.
Talcose schist, slightly unctuous.
Pea-green and easily decomposing talcose schist, abounding in veins of calcite and transparent fetid quartz.
Gritty talcose schist, Middlesex east line.
Talcose schist, slightly unctuous.
Compact talcose schist, slighty unctuous.
Soft argillo-talcose schist.
Talcose schist, somewhat unctuous.
Very gritty talcose schist.
Light green talcose schist.
Bright green talcose schist, rather soft.
Novaculite schist.
Gritty talcose schist.
Very soft and unctuous talcose schist.
Clay slate, or shales.
Very soft and unctuous talcose schist.
Plumbaginous shales.
Beds of gritty talcose schist.
Green novaculite schist (slaty.)
Occasional strata of nearly pure brown quartz.
Bright green talcose schist.
Very soft novaculite schist.
Novaculite schist.
Stratum of coarse talcose grit.
Compact bright green novaculite schist.
Soft and unctuous novaculite schist.
Clay slate.
Compact soft talcose schist.
Talcose schist, soft and shining with veins of granular dolomite.
Talcose schist, weathering white.
Gneissoid talcose schist (feldspar probably, or pebbles.)
Talcose schist (altered sandstone.)
Talcose schist, intermixed with white granular limestone.
Serpentine soapstone, chlorite, massive hornblende, etc. associated together in Moretown.
Talco-micaceous schist.
Beds quartz rock mixed with coarse talcose schist.
Thick mass of white limestone.
Talcose schist passing into gneiss.
Gneiss in Duxbury and Waterbury.

There are of course several rocks not talcose, associated with the schists in the foregoing section. It will give a good idea of the formation, and under the several general sections similar descriptions of this formation will be found. The total thickness of the strata upon this particular section must be several thousand feet.

7. *Quartz, Talc* or *Talcite, and Mica.* This is generally called *talco-micaceous schist.* It may be considered either as mica schist, which takes into its composition more or less of talc, or as talcose schist, containing mica. Talc and mica resemble each other so much when disseminated in their corresponding schists, that sometimes it is extremely difficult to say whether the specimen before us is micaceous or talcose. Much of the talcose schist contains more or less of mica. This is more especially true in the southern part of the State, in Massachusetts, and in parts of the east and west ranges in northern Vermont. Indeed we have tried to show elsewhere, that a talcose schist (i. e. nacreous) may change into gneiss, and thus the mineral resembling talc be changed into mica. We do not doubt but that the superabundance of micaceous minerals, even in this formation, in the south part of the State, is an alteration from the more perfect talcose schists, as the rocks grow more metamorphic as we proceed southwards from Canada line. Specimens of these varieties are numerous upon the southern sections in the Cabinet.

8. *Talcose Schist, with carbonates of lime and oxyd of iron.* Much of the talcose schist effervesces with acid, indicating the presence of a carbonate. This is doubtless either a carbonate of lime, or of the protoxyd of iron. Wherever the white carbonate of lime can be seen in the specimen, or near the locality, no doubt can be entertained that the effervescence is due to carbonate of lime. In other cases, there is reason to suppose that the additional mineral is carbonate of the protoxyd of iron. It is very common to see decomposed masses of schist colored by iron rust. This probably results from the decomposition of this mineral. It is said that this carbonate occurs where masses of quartz exist of considerable size. The carbonate of lime is most abundant in the north part of the State; and there is reason to suppose that still further to the northeast, the lime is still more plentiful. Connected with metamorphism, in some way not fully understood, there is a strong tendency in nature to substitute silica for carbonate of lime, and that sometimes quite abruptly. The talcose and mica schists strongly exemplify this statement in Vermont.

The carbonate of the protoxyd of iron is most abundant in the east part of the middle range of talcose schist in the vicinity of the gold deposit, indeed the gold is found with the crystals of the carbonate.

9. *Talc* (?), *Quartz and Hornblende* or *Hornblende Schist.* This variety is exceedingly common: forming in the most thoroughly metamorphic portion of the formation, about one-fourth of the whole. It occurs as a slate, as compact thick-bedded schists, as pure hornblende, as hornblende and quartz or feldspar, or as in the heading. It may perhaps be true that a talcose schist will alter into hornblende schist. Along the eastern margin of the middle range of the schists it is the most abundant. The mineral hornblende is sparingly distributed over the whole formation.

10. *Talc* (?), *Feldspar and Quartz.* This variety is intermediate between talcose schist and gneiss ; and differs from the latter rock only by the substitution of talc for mica. It is obviously, however, a rock more mechanical in its character than gneiss : the feldspar existing in coarse grains. This is found in what we term a porphyritic talcose schist. Or it may approach gneiss in its character, especially near the gneiss and gneissoid rocks of the Green Mountains. The feldspar may not be suspected to be present except by examining the edges of the strata freshly fractured.

11. *Novaculite Schist.* This is a new term in geology. Novaculite however is an old term, and rather an indefinite word also. It has been used to denote a variety of clay slate composed of silica, alumina and an alkali. But mineralogists are always careful not to state much that is definite respecting it. We find no mention of it in the latest treatises upon mineralogy ; and yet it is more worthy of mention than one-fourth of the substances enumerated. It is regarded as a sort of unknown genus to which everything doubtful can be thrown as to a general receptacle. We understand by the term novaculite what is popularly known as honestone or whetstone ; a mineral of perfectly homogeneous but not crystalline structure, with the composition (as before stated) of silica, alumina and alkalies, not very different from the most homogeneous of talcose schists. It is generally unctuous like talc, and the purest portion of the novaculite would perhaps

be called talc were it not too hard. We use the term *novaculite schist* to embrace all the pure and impure varieties of novaculite in Vermont. They are not confined to the formation now under consideration, but are connected with all the ranges of clay slate.

The novaculite schist connected with the talcose schist is mostly confined to one or two narrow belts in the east part of the middle range, between Northfield and Memphremagog. North of Craftsbury the novaculite is much prized for honestones; those from Lake Memphremagog being very highly prized. In the west part of Coventry, and upon all the northern sections, excellent novaculite is found. Upon Section IX. and elsewhere it degenerates into an impure article, unfit for hones, and passing gradually into the soft talcose schist. But there is an immense amount of this inferior quality of novaculite in this formation. Novaculite schist also abounds in Franklin, Berkshire, etc. upon the western range.

12. *Epidotic Talcose Schist.* This is a curious rock, and almost deserves a separate color upon the map. It is all contained in a strip two miles wide and eight miles long (in Vermont), in the towns of Berkshire and Enosburgh. The rock is chlorite schist full of nodules or geodic masses of epidote. The larger ones average an inch in diameter, and sometimes are six or eight. Generally the bunches are a quarter of an inch thick, and are very thickly disseminated so that the rock resembles amygdaloidal trap. Calcite and specular iron are often associated with the epidote. These three minerals are all in crystals and well defined. The strata are nearly perpendicular over the whole of this district. This rock is universally regarded as metamorphic. Even those geologists who deny that the gneiss and talcose schist of the Green Mountains are metamorphic admit that the presence of "nests of epidote and calcite" are sure evidence of a change from a sedimentary to a crystalline state. In the Cabinet Nos. $\frac{13}{144}$ and $\frac{13}{145}$ illustrate the characters of this rock.

13. *Whetstone Talcose Schist.* This term is applied to an arenaceous variety, almost a sandstone in some cases, which is widely used for the purpose indicated by the name. It is of a light gray color, compact, and softer than sandstone. Excellent localities of it are in Ludlow, on Abel Adams' land, where it is quarried for whetstones (No. $\frac{5}{112}$) ; in Marlboro ; the north part of Fairfield (No. $\frac{11}{124}$) ; at Plymouth ; in the south part of Stockbridge, upon the land of Mr. Esty ; and elsewhere, particularly in the middle parts of the State.

ROCKS ASSOCIATED WITH TALCOSE SCHISTS AND CONSTITUTING INTEGRAL PARTS OF THE FORMATION.

These are clay slate, with plumbaginous, aluminous and pyritiferous varieties ; hornblende schist, gneiss, quartz rock, sandstones and conglomerates, limestones and dolomites. Of these the hornblende schists and limestones are considered under separate headings as rocks by themselves.

1. *Clay Slate.* There is a distinct belt of this variety in each of the two principal ranges. One commences at North Troy, and may be traced southerly through Troy, Lowell, Eden, Hydepark, Morristown, Stow, Worcester and Middlesex. South of Middlesex, along the same general strike, the same belt is seen in Braintree, Rochester, Sherburne and Bridgewater. Want of observation alone prevents us from joining these two lines upon the Map. It probably is found nearly continuously through the State to Massachusetts, disguised sometimes as hornblende slate or schist in the more thorough metamorphic region. Plumbaginous shales may be another form in which this variety is disguised. This occurs at Halifax, Somerset, Proctorsville, Bridgewater, Plymouth, Sherburne, Hancock, Cambridge and elsewhere. Those at Hancock and Cambridge are valuable as plumbago.

The range west of the Green Mountains is in the towns of Richford, Montgomery, Avery's Gore, Belvidere, Waterville, Cambridge, Underhill, Jericho, Bolton and Huntington. It is marked upon the map. We have a glimpse of a fourth range of clay slate in Sheldon, Fairfield and Westford. The character of these ranges is rather that of shales than of distinct clay slate, except at intervals ; as in the northern part of the eastern range they are invariably black, except when from the decomposition of pyrites they have the color of iron rust.

The pyritiferous variety includes those strata, not always argillaceous, in which there are a great many crystals of iron pyrites. At least a fourth part of the three ranges is more or less stained by this rust. In the west range, through Underhill, Jericho, Bolton and Huntington, a ferruginous strip is particularly noticeable. In Hydepark, Morristown and Worcester there is another unusually ferruginous, in which gold and associated minerals occur. Other localities are too numerous to mention, and many are noticed upon the section.

Aluminous slate is connected with these imperfect clay slates. The sulphuric acid for the alum results from the sulphur of the pyrites, and the alum produced is an iron alum. Copperas also may result; but both these compounds do not accumulate because they are washed away by the rain and snows.

2. *Gneiss.* This is not abundant. It is chiefly found along the borders of the formation where it connects with gneiss. Specimens of gneiss in talcose schist have been obtained from Marlboro, Wilmington, Proctorsville, Ludlow and Plymouth.

3. *Quartz Rock.* In the town survey of Plymouth, Mr. Hager found that there were two beds of quartz (See Plate XVIII) in the talcose schist running through the town. Their curves are due to the topography of the surface. The character of the quartz is that of a milky white or else transparent variety. Without doubt a careful exploration would discover that these two belts are continuous throughout the State. They are quite near each other, and hence might be confounded together elsewhere; and hence we will mention the localities in other parts of the State, which may possibly be the continuation of these in Plymouth, West Marlboro, South Wardsboro, North Wardsboro, Ludlow, Bridgewater, Rochester, Middlesex; and in Johnson there are two beds of quartz rock each ninety feet thick. About Hazen's Notch for five or six miles the surface is covered with bowlders of a very tough quartz rock. A range of a similar rock, says Rev. S. R. Hall, is found near the top of the Green Mountains through the whole State. Probably this range is the same with the one in Plymouth. Other masses of quartz are common through the talcose schist, especially thin strata of brown quartz. They will be found mentioned upon the catalogue, and are of too little consequence to be specified separately.

4. *Sandstones and Conglomerates.* Considerations have been presented to show that talcose schist may be produced from sandstone by metamorphism. Much of the schist was probably sandstone originally. The east part of the western range is now clearly a sandstone, as may be seen among the specimens upon Section XI. The grains of sand are cemented by talcose matter, and the whole rock is very compact.

The section along Winooski River exhibits several strata of sandstone. The amount increases upon each section north. In Hydepark and Wolcott it is better characterized than on Section IX, and in Troy it is quite distinct. In Canada along the line of strike, very much of the rock is sandstone — the Sillery sandstone of the Canada Survey. A large bowlder from Canada was examined as it lay in the north part of Brownington, and was found to be a conglomerate of quartzose fragments, and pieces of limestone containing pentacrinites. Nothing of that description has been found *in situ* in Vermont.

A single bed of a very coarse conglomerate occurs in Coventry at Charles Wright's house in the northwest part of the town, and also three miles south, which is doubtless of the same age with the bowlder.— The fragments are from two inches to over two feet in diameter, being composed of various kinds of slates and schists, some of which are decomposing quartz pebbles, granite pebbles, etc. It is more interesting because it is at the base of the talcose schist formation, overlying a narrow bed of upper Silurian limestone and clay slate. Nothing elsewhere in the State is like it, unless it be a coarse conglomerate passing into porphyry upon Little Ascutney.

5. *Igneous Rocks associated with this formation.* There are small outbursts of granite, several trap dikes, and a few ledges of concretionary granite like that at Craftsbury in the calciferous mica schist. A semi-igneous rock in a breccia with a syenitic paste is in Barnet upon Connecticut River. A breccia without this paste occurs further south at Newbury. Connected with it is a very indurated talcose schist, slightly resembling serpentine. A coarse rock with black spots of argillaceous matter more or less calcareous is abundant about White River Junction. The eastern range is different from the others by being largely composed of these rough semi-igneous brecciated rocks. They will be described fully under igneous rocks.

There is an indurated talcose schist in the southeast part of Troy at Levi Brooks' house. It passes into granite. Granite is also found in the talcose schist in Plymouth (See Plate XVIII), Braintree, northeast part, where the area covered is as much as two square miles (C. B. A.), in Waterbury and Lowell. Trap dikes have been noticed and will be described in the talcose schist, in the towns of Newbury, Warren, Stockbridge, Bolton, Richmond and Enosburgh. Dikes are comparatively few in the talcose schist regions. The concretionary granite is found in the talcose schist in Waterford, Northfield and Proctorsville. In the southeast part of Huntington there is a coarse syenitic rock.

Divisional Planes.

The principal class of divisional planes in this formation are joints. Cleavage is rarely seen, unless we have greatly overlooked its indications, and we have certainly labored hard to find them, with but little success. Foliation may be found, but we think that in general it corresponds with the planes of stratification. Except in a few cases, and many of those in a coarse talcose conglomerate on the borders of the west range of talcose schist, described under talcose conglomerate, we have found no planes referable to foliation distinct from the strata. These cases are described and figured under the details of that rock.

The conjecture may arise in many minds that perhaps the original planes of stratification have been entirely obliterated in this and some other metamorphic rocks, so that our efforts to measure the thickness of the strata is utterly futile, and the results monstrous. But we are not satisfied with the theory that foliation, or any other known cause can so completely separate the different kinds of rock into separate bands associated with each other, that they cannot be distinguished from what are universally admitted to be strata. Can foliation separate beds of limestone, steatite, and serpentine, from the schists, causing them to lie at right angles to the original strata? This must be admitted if it is held that the apparent strata of the metamorphic rocks are not the true strata. If otherwise, the difficulty from the great thickness will still remain; for many of these beds are perpendicular, as well as the adjoining schists.

If it were possible that the original strata were from two to four feet thick, there are joints in a few localities, thus remote from one another, dipping at a small angle. But they are irregular, and frequently are not parallel to one another; and moreover, the rapid changes of their inclination militate against the supposition that these planes could ever have been the boundaries of strata. Upon the whole, then, we cannot depart from the old theory of the true dip and strike of the strata of at least the talcose schist, without violating other geological laws of greater importance; and we must, therefore, adopt unflinchingly whatever results may flow from it.

We have taken a few observations that we venture to call foliation or something analogous to cleavage planes, in distinction from the true strata. Both these observations and those of the joints were taken by C. H. Hitchcock, and hence it is unnecessary to add the initials of his name to each observation — according to our custom — after the general statement.

[The locality, strike, dip of cleavage, and dip of strata are given.]

Hydepark, strike N. 37° E., dip of cleavage 73° E., dip of strata 90°. East Hydepark, strike N. 37° E., dip of cleavage 73° W., dip of strata about 90°. Wolcott, strike east of north, dip of cleavage 75° E., dip of strata 90°. Richmond, strike transversely to the strike of the strata.

It is remarkable that these planes have a smaller inclination than the planes of stratification.

POSITION OF THE JOINTED PLANES.

East Middlesex, strike N. 30° E., dip of cleavage 25° E., dip of strata 75° W. East Middlesex, dip of cleavage 9° E., dip of strata about do. Middlesex, strike east of north, dip of cleavage 10° E. in two places, dip of strata west. West Middlesex, strike E. and W., dip of cleavage 90°, dip of strata 80° W. Proctorsville, strike E. and W., dip of cleavage 90°, dip of strata average 75° W. Bolton, west part, strike N. 80° W., dip of cleavage 80° S., dip of strata 75° W. North Westford, dip of cleavage 7° S., dip of strata 90°. Johnson, center, strike N. 20° W., dip of cleavage 70° S., dip of strata 60° E. Hydepark, strike N. 37° E., dip of cleavage 23° S., dip of strata 90°. Hydepark, strike N. 37° E., dip of cleavage 12° S., dip of strata 90°. East Hydepark, strike N. 35° E., dip of cleavage 25° E., dip of strata average 40° E. East Hydepark, strike N. 57° W., dip of cleavage 90°, dip of strata average 40° E. East Hydepark, strike E. and W., dip of cleavage 75° S., dip of strata average 40° E. Wolcott, strike E. and W., dip of cleavage 75° S., dip of strata 90°.

STRIKE AND DIP OF THE STRATA.

RANGE ALONG THE CONNECTICUT RIVER.

[The locality, strike and dip, and initials of the Observer are given.]

Guildhall, strike N. 45° E., dip 90°, C. H. H. Granby, strike about N. 45° E., dip 65° N.W., C. H. H. Victory strike N. 20° E., dip 50° E., C. H. H. Lunenburgh, west part, strike N. 45° E., dip about 90°, A. D. H. Concord, east part, strike N. 27° E., dip 86° E., C. B. A. Concord, south part, strike N. 20° E., C. B. A. Waterford, northeast part, strike N. 40° E., dip 75° S.E., C. B. A. Waterford, lower village, dip 65° E., C. H. H. Waterford, southwest part, strike N. 38° E., dip 70° S.E., C. B. A. Waterford, southwest part, strike N. 38° E., dip 80° S.E., C. B. A. Barnet, northeast part, strike east of north, dip 85° E., C. H. H. Littleton, N. H., dip 90°, C. H. H. Newbury, north part, strike N. 35° E., dip 85° N.W., C. B. A. Newbury, north of village, strike N. 40° E., dip 76° N.W., E. H. Newbury, village, strike N. 45° E., dip 82° S.E., C.H.H. Newbury, south of do., strike N. 25° E., dip 80° E., C. H. H. Newbury, strike N. 10° E., dip 80° E., A. D. H. Newbury, strike about the same, dip 90°, A. D. H. Newbury, west of village, strike N. 5° E., dip 85° E., A. D. H. Newbury, southeast part, strike N. 35° E., dip 85° N.W., C. B. A. Newbury, south part, dip about 80° E., C. H. H. Bradford, northeast part, strike N. 35° E., dip 85° N.W., C. B. A. and A. D. H. Thetford, northeast part, strike N. 15° E., dip 85° W., C. B. A. Thetford, northeast part, strike N. 15° E., dip 84° E., C. B. A. Thetford, east part, strike N. 35° E., dip 45° N.W., C. B. A. Thetford, south part, strike N. 35° E., dip 80° N.W., C. B. A. Thetford, south part (steatite), strike E. and W., dip 42° N., A. D. H. Thetford, adjacent to the steatite, strike N. 35° E., dip 38° W., A. D. H. Thetford, southeast part, strike N. 33° E., dip 30° W., C. B. A. Thetford, southeast part, strike N. 33° E., dip 60° W., C. B. A. Thetford, south line, strike N. 20° E., dip 45° W., A. D. H. Thetford, south line, strike N. 20° E., dip 42° E., A. D. H. Thetford, strike N. 24° E., dip 35° E., C. H. H. Thetford Hill, dip 80° E., A. D. H. Norwich, strike N. and S., dip 75° W., C. B. A. Norwich, center, strike N. 37° E., dip 70°–75° W., C. H. H. and A. D. H. Norwich, center, strike N. 25° E., C. H. H. White River Village, strike N. 30° E., dip 70° E., C. H. H. Hartford, strike east of north, dip 90° nearly, C. H. H. and A. D. H. Hartford, strike N. and S., dip 75° W., C. B. A. Hartford, "copper mine," strike N. 20° E. (rarely N. 50° E.), dip 85° E.–85° W., A. D. H. Springfield, east part, strike N. 5° E., dip 50° W. Springfield, east part, strike N. 5° E., dip 75° W., C. B. A.

GREAT CENTRAL RANGE.

Halifax, strike N. 35° E., dip 90°, C. H. H. West Halifax, strike N. 45° E., dip 65° S.E., C. H. H. and A. D. H. Halifax, west line, strike about the same, dip 40° E., C. H. H. Halifax, west line, strike N. 10° W., dip 15° E., C. B. A. Marlboro, dip 30° E. and 25° E., C. H. H. Marlboro, Methodist church, strike N. 70° E., dip 18° N., C. H. H. Marlboro, Ballou's steatite, strike N. 20° E., dip 50° E., C. H. H. and A. D. H. Marlboro, Belus' steatite, strike N. 20° E., dip 50° E., C. H. H. and A. D. H. Marlboro, Worden's steatite, strike N. 10° E., dip 50° E., C. H. H. and A. D. H. Marlboro, west of church, strike N. 32° E., dip east exceedingly variable, 15°–70°, C. H. H. Marlboro, west part, strike N. 45° E., dip about 90°, C. H. H. Marlboro, west line, strike N. 45° E., dip 75° W.–90°, C. H. H. Wilmington, east part, strike N. 36° E., dip 50° S.E., C. B. A. Newfane, west part, strike N. 15° E., dip 77° E., E. H. Newfane, east of do., strike N. 10° E., dip 50° W., C. H. H. South Wardsboro, dip 25° W., C. H. H. South Wardsboro, strike N. 40° E., dip easterly, C. H. H. Wardsboro, dip 40° E. (synclinal axis), C. H. H. Newfane, northwest part,

strike N. 5° E., dip 78° W. and 58° E., C. H. H. Wardsboro, north part, dip 20° E. and 25° southerly, C. H. H. North Wardsboro, strike N. 65° W., dip 45° S.W., C. H. H. North Wardsboro, dip 21° W. and horizontal, C. H. H. North Wardsboro village, dip 20° E., C. H. H. Windham, southeast part, strike N. 15° E., dip 46° E., C. H. H. Windham, south part, strike N. and S., dip 70° E., C. B. A. Windham, Greely's serpentine, strike N. 10° E., dip 60° E., C. H. H. Proctorsville, strike N. 17° E., dip 80° E., C. H. H. Proctorsville, strike N. 5° E., dip 58° E., C. H. H. Proctorsville, strike east of north, dip 75° E., C. H. H. Proctorsville, dip 66° E., C. H. H. Proctorsville, strike N. 20° E., dip 79° E., C. H. H. Proctorsville, strike N. 30° E., dip 90°, C. H. H. Ludlow, east part, strike N. 15° E., dip 79° E., E. H., jr. Ludlow, east part, strike N. 15° E., dip 60° E., E. H., jr. Ludlow, south part, strike N. 10° E., dip 68° E., A. D. H. Ludlow, soapstone beds, strike N. 10° E. Ludlow, west part, strike N. and S., dip 50° E. and 60° E., A. D. H. Ludlow, west part, strike N. 10° E., dip 65° E., C. A. W. Ludlow, dolomite bed, strike N. 20° E., dip 65° E., A. D. H. Ludlow, railroad cut, strike N. 46° E., dip 80° E. to 90°, E. H., jr. Ludlow, railroad cut, strike N. 20° E., dip 40° E., E. H., jr. Plymouth, chalybite bed, strike N. 10° E., dip 55° E., E. H., jr. Plymouth, near do., strike N. 16° E., E. H., jr. Plymouth, gold rock, Carlisle's, strike N. 20° E., dip 75° E., A. D. H. Plymouth, west of pond, strike N. 10° E., dip 55° E., C. A. W. Plymouth Pond, strike N. 10° W., dip 45° E., C. A. W. Plymouth, south part, strike N. 5° E., dip 35° E., C. B. A. Plymouth, iron mine, strike N. 20° E., dip 45° E., C. A. W. Plymouth, Frog city, strike N. 10° E., dip 52° E., C. A. W. Plymouth, do., adit, strike N. 10° E., dip 30° E., C. A. W. Plymouth, north part, strike N. 10° E., dip 70° E., C. B. A. Plymouth, south part, strike N. and S., dip 39° E., C. H. H. Bridgewater, west part, strike about N. and S., dip 60° E., C. B. A. Bridgewater (quartz stratum) strike N. and S., dip 40° E., E. H., jr. Bridgewater, gold mine, strike N. 20° E., dip 30° E., C. H. H. Bridgewater, steatite, strike about N. and S., dip 35° E., A. D. H. Bridgewater village, strike N. 20° E., dip 30° E., C. H. H. and A. D. H. Stockbridge, east part, strike N. and S., dip 40° E., C. B. A. Stockbridge, village, strike N. 10° W., dip 40° E., C. B. A. Goshen, east part, strike east of north, dip 40° E., C. H. H. Rochester, west line, strike N. 15° E., dip 30°–50° E., C. H. H. West Rochester, strike E. of N., dip 45° E., C. H. H. Rochester, strike N. 80° E., dip 50° E and 45° E., C. H. H. Rochester, village, strike N. 10° W., dip 40° E., A. D. H. Rochester, strike N. and S., dip 45° E., A. D. H. Rochester, east of village, strike N. 5° W., dip 45° E., A. D. H. Rochester, east of village, dip nearly 90°, A. D. H. Rochester, Williams' steatite, dip 40° W., to 90°, A. D. H. Rochester, east part, strike N. and S., dip 30° W., A. D. H. Rochester, east line, dip 10°–40° W., A. D. H. Bethel, west part, strike N. and S., dip 70° E., A. D. H. Bethel, west part, strike N. and S., dip 90°, A. D. H. Bethel, west part, strike N. and S., dip 70° E., C. B. A. Bethel, near middle, strike N. 5° E., dip 51° E., C. B. A. Bethel, strike N. 45° W., dip 45° S.E., A. D. H. Bethel, near village, dip 72° E., A. D. H. Bethel, north corner, strike N. 10° W., dip 80° W., C. B. A. Hancock, center, strike N. 20° E., dip 70° E., C. H. H. Hancock, south part, strike N. 5° W, dip 73° E., C. H. H. and A. D. H. Hancock, strike N. and S., dip 66° E., C. B. A. Sherburne, strike N. and S., dip 60° E., E. H., jr., and C. H. H. Sherburne, east of hotel, strike N. and S., dip 60° E., C. H. H. Windham, north part, strike N. 10° E., dip 70° E., C. H. H. Granville, south line, strike N. and S., dip 65° E., C. B. A. Granville, south part, strike N. and S., dip 55° E., C. B. A. Granville, north part, strike N. and S., C. B. A. Granville, north part, strike N. 20° E., dip 63° E., C. H. H. Granville, north part, strike N. 20° E., dip easterly, C. H. H. Braintree, middle, strike N. and S. dip 90°, C. B. A. Warren, near middle, strike N. and S., dip 50° E., C. B. A. Warren, north part, strike N. 5° W., dip 58° E., C. B. A. Warren, east line, strike N. 20° E., dip 90°, C. H. H. Warren, center, strike N. 20° E., dip 90°, C. H. H. Warren, south part, strike N. 20° E., dip 65° E., C. H. H. Roxbury, west line, strike N. and S., dip 80° E., C. B. A. Roxbury, south part, strike N. 5° W., dip 78° E., C. B. A. Roxbury, south part, strike N. and S., dip 80° W., C. B. A. Roxbury, north part, strike N. and S., dip 80° W., C. B. A. Roxbury, verd-antique serpentine, strike N. 22° E., dip 80° W., C. H. H. and A. D. H. Roxbury, west part, strike N. 20° E., dip 90°, C. H. H. Roxbury, north part, strike N. 23° E., dip 84° W.–90°, C. H. H. Northfield, center, strike N. 10° E., dip 75° W., C. B. A. & Z. T. Northfield, northwest part, strike N. 12° E., dip 90°, C. B. A. Northfield, northwest part, strike N. 19° E., dip west, Z. T. Waitsfield, near village, strike, N. 30° E., dip 80° E., A. D. H. Waitsfield, middle, strike N. and S., dip 80° E., C. B. A. Berlin, strike N. 5° E., dip 80° W., C. B. A. Berlin, middle, strike N. 8° E., dip 90°, C. B. A. Berlin, north part, strike N. 10° E., dip 76° W., C. B. A. Berlin, north corner, strike N. 10° E., dip 78° W., C. B. A. Montpelier, at Catholic Church, strike N. 35° E., dip 67° E., C. H. H. Montpelier, between Catholic Church and State House, strike, N. 50° E., dip 65° W., C H. H. Montpelier, at the State House, strike N. 45° E., dip 72° W., C. H. H. Montpelier, north of State House, strike N. 35° E., dip 73° W., C. H. H. Montpelier, village, strike N. 15°–20° E., dip 65°–75 W., Z. T. Montpelier, west of village, strike N. 20° E., dip 76° W., C. H. H. Montpelier, west part, strike N. 12° E., dip 80° W., C. B. A. Middlesex, east part, strike N. 20° E., dip 76° W., C. H. H. Middlesex, east part, strike N. 10° E., dip 80° W., C. B. A. Middlesex, east part, strike N. 35° E., dip 85° W.,

Z. T. Middlesex, middle of east line, strike N. 30° E., dip 75° W., C. H. H. Middlesex, near center, dip 67° W., C. H. H. Middlesex, near center, strike N. 12° E., dip 80° W., C. B. A. Middlesex, center, dip about perpendicular, C. H. H. Moretown, south part, strike N. 10° E., dip 86° W., C. B. A. Moretown, mouth of Mad River, dip 90°, C. H. H. Moretown, on Mad River, strike N. 18° E., dip 84° W., Z. T. Moretown, height of land two miles east of Mad River, strike N. 4° E., dip 86° W., Z. T. Moretown, east of steatite, strike N. 35° E., dip 90°, C. H. H. and A. D. H. Moretown, steatite bed, strike N. 20° E., dip 85° W., Z. T. Moretown, northwest corner, strike N. 8° E., dip 90°, C. B. A. Moretown, northwest corner, strike N. 25° E., dip 75° E., C. H. H. Moretown, near beds of limestone, strike N. 17° E., dip 90°, C. H. H. Duxbury, east part, dip near 90°, C. H. H. Duxbury, opposite Waterbury street, strike N. 14° E., dip 59° E., Z. T. Duxbury, one mile south of Waterbury street, strike N. 20° E., dip 57° E., Z. T. Duxbury, two and a half miles south of Waterbury street, strike N. 20° E., dip 80° E., Z. T. Duxbury, three miles south of Waterbury street, strike N. 20° E., dip 70° E., Z. T. Duxbury, middle of east line, strike N. 2° E., dip 80° E., Z. T. Duxbury, near Waterbury bridge, strike N. 3° E., dip 86° E., Z. T. Waterbury street, west of, strike N. 17° E., dip 57° E., C. H. H. Waterbury street, west of, strike N. 17° E., dip 50° E., C. H. H. Waterbury street, one-half mile west, strike N. 17° E., dip 85° E., Z. T. Waterbury, between street and center, strike N. 19° E., Z. T. Waterbury street, east of, strike N. 15° E., dip 90°, C. B. A. Waterbury, south of center, strike N. and S., Z. T. Waterbury, north part, dip 85° E., Z. T. Stow, Waterbury line, strike N. 11° E., dip 75° E., Z. T. Stow, two miles south of center, strike N. 20° E., dip 65° E., Z. T. Stow, east part, strike N. 30° E., Z. T. Stow, center, strike N. 24° E., dip 85° E., Z. T. Worcester, north part, strike N. 26° E., dip 87° W., Z. T. Worcester, near Middlesex line, strike N. 23° E., dip 82° W., Z. T. Worcester, south part, strike N. 25° E., dip 80° W., C. B. A. Elmore, one mile south of church, strike N. 22° E., dip 80° E., Z. T. Elmore, near church, strike N. 24° E., dip 90°, Z. T. Elmore, Eagle ledge, strike N. 40° E., dip 90°, C. H. H. Morristown, near center, strike N. 10° E., dip 90°, Z. T. Morristown, near Morrisville, strike N. 25° E., dip 84° W., S. R. H. Morristown, Cady's Falls, strike N. 25° E., dip 85° W., S. R. H. Morristown, lead vein, strike N. 10° E., dip 85° W., Z. T. and A. D. H. Morristown, near Morrisville, strike N. 16° E., dip 90°, Z. T. Morristown, northeast part, strike N. 37° E., dip 73° E., C. H. H. Morristown, northeast part, strike about the same, dip 73° W., C. H. H. Wolcott, west corner, strike N. 23° E., dip 90°, C. H. H. Wolcott, west part, strike about the same, dip 85° W., and 90°, C. H. H. Wolcott bridge, one mile west of village, strike N. 25° E., dip 72° E., Z. T. Wolcott, three miles below La Moille River, strike N. 22° W., dip 70° E., Z. T. Wolcott, near La Moille River, strike N. 35° E., dip 75° E., Z. T. Wolcott, south part, strike N. 30° E., dip 70° E., Z. T. Wolcott, west branch, strike N. 13° E., Z. T. Wolcott, east line, strike N. 20° E., dip 72° E., A. D. H. Hardwick, west part, strike N. 40° E., dip 75° E., C. H. H. Hardwick, south part, strike N. 20° E., dip 60° E., A. D. H. Hydepark, southeast corner, strike N. 35° E., dip 45° W., A. D. H. Hydepark, southeast part, strike N. 35° E., dip 35°–54° W., C. H. H. Hydepark, southeast corner, strike about the same, dip 10°–12° W., C. H. H. Hydepark, northeast part, strike N. 30° E., dip 90°, S. R. H. Hydepark, Green River Falls, strike N. 25° E., dip 41° E., S. R. H. Hydepark, two miles west of Green River Falls, strike N. 30° E., dip 75° W., S. R. H. Hydepark, Court House, dip 90°, C. H. H. Hydepark, west of Court House, strike N. 26° E., dip 75° E., A. D. H. Hydepark, one mile west of Court House, strike N. 25° E., dip 65° E., S. R. H. Hydepark, two miles west of Court House, strike N. 20° E., dip 75° E., A. D. H. Hydepark, west part, strike N. 25° E., dip 65° E., S. R. H. Johnson, one mile east of village, strike E. of N., dip 45° E., C. H. H. Johnson, center, strike N. 10° E., dip 60° E., C. H. H. Johnson village, one mile north of, strike about the same, dip 60° E., C. H. H. Johnson, north part (limestone bed), strike N. 40° W., dip 50° N.E., C. H. H., 60° E., Z. T. Johnson, just west of limestone bed, strike N. 40° W., dip 30° E., C. H. H. Craftsbury, west part, strike N. 30° E., dip 75° W., S. R. H. Eden, C. A. W. Lowell, east of village, strike N. 65° E., dip 70° N.W., C. B. A. Coventry, strike N. 40° E., dip 50° N.W., C. H. H. Coventry, southwest corner and Irasburgh line, strike N. 10° E., dip 60° W., C. B. A. Newport, a mile west of Magog Lake, strike S. 25° W., dip 60° W., S. R. H. Newport, two miles west of lake, strike S. 50° W., dip 70° N.W., S. R. H. West Newport to South Troy, strike S. 25° W.–S. 50° W., dip 75° W.–90°, S. R. H. South Troy, a mile east, strike N. 25° E., dip 90°, C. H. H. Troy, West Falls, strike N. 25° E., dip 90°, C. H. H. North Troy, High Falls, strike N. 30° E., dip 70° W., S. R. H. North Troy, near mills, strike N. 10° E., dip 80° E., S. R. H. Jay, steatite bed, strike N. and S., dip 90°, C. H. H. Potten, C. E., strike N. 45° E., dip 55° S.E., C. H. H. Owl's Head, Potten, C. E., dip to the west, C. H. H.

RANGE WEST OF THE GREEN MOUNTAINS.

Lincoln, village, strike N. and S., dip 73° E., C. B. A. Lincoln, east of village, strike N. and S., dip 53° E., C. B. A. Lincoln, east of village, strike N. and S., dip 50° E., C. H. H. Huntington, east part, strike N. 15° E., dip

75° E., C. B. A. and C. H. H. Huntington, south village, strike N. and S., dip 50° E., C. B. A. Huntington, east of center, strike N. 2° E., dip 90°, Z. T. Huntington, a half mile north of center, strike N. 10° W., dip 86° E., Z. T. Huntington, Hinesburgh line, strike N. 10° E., dip 70° E., C. H. H. and A. D. H. Richmond, south part, strike N. 10° E., dip 69° E., C. H. H. and A. D. H. Richmond, easterly part, strike, N. and S., dip 90°, C. B. A. Richmond, two miles below village, strike N. 2° E., Z. T. Richmond, at turnpike bridge, strike N. 6° E., dip 74° E., Z. T. Jonesville, east of depot, strike N. 20° E., dip 90° and variable, C. H. H. Jonesville, west of depot, strike N. 20° E., dip 73° E., C. H. H. Jonesville, a mile west, strike N. 10° E., dip 65° E., C. H. H. Richmond, west of do., strike N. 10° E., dip 65° E., C. H. H. Richmond, west of previous, strike N. 10° E., dip 65° E., C. H. H. Richmond, half mile east of center, strike N. 14° E., dip 72° W., Z. T. Richmond, west part, strike N. 10° E., dip 74° E., C. B. A. Underhill, near village, strike N. 40° E., dip 90°, Z. T. Underhill, a mile west of village, strike N. 20° E., dip 60° E., A. D. H. Underhill, west foot of Mansfield Mountain, dip 70° W., Z. T. Westford, central parts, strike N. 10° E., dip 80° E., C. B. A. Westford, east part, dip about 75° E., S. R. H. Westford village, half a mile east, strike N. 20° E., dip 85° E., S. R. H. Westford, N. 10°–20° E., dip 85° W., S. R. H. Fairfax, south part, strike N. 10° E., dip 80° E., C. B. A. Fairfax, north of village, strike N. 35° E., dip 75° E., C. B. A. Fairfax, northeast part, strike N. 25° E., dip 70° E., C. B. A. Fairfield, north part, strike N. 35° E., dip 60° S.E., S. R. H. Fairfield, north part, strike N. 35° E., dip 65° S.E., S. R. H. Fairfield, St. Rocks, strike N. 50° E., dip 60° S.E., S. R. H. Fairfield, St. Rocks, strike N. 50° E., dip 80° N.W., and 84° S.E., S. R. H. Fairfield, north of St. Rocks, strike N. 45° E., dip 80° S.E., S. R. H. Fairfield, Burr's mine, strike N. 35° E., dip 80° S.E., C. H. H. Fairfield, near Fletcher line, strike N. 30° E., dip 75° E., C. B. A. Fairfield, south part, strike N. 30° E., dip 75° E., C. B. A. Fairfield, east part, strike N. 30° E., dip 75° E., C. B. A. Bakersfield, west part, strike N. 15° E., dip 80° E., C. B. A. Bakersfield, northeast corner, strike N. 15° E., dip 75° W., C. B. A. Enosburgh, center, strike N. 17° E., dip 90°, Z. T. Enosburgh, center, strike N. 32° E., dip 66° S.E., S. R. H. Enosburgh, east part, strike N. 30° E., dip 60°–70° S.E., S. R. H. Enosburgh, west of center, strike N. 34° E., dip 85° W., S. R. H. West Enosburgh, strike N. 60° E., dip 85 N.W., S. R. H. Enosburgh, west part, strike N. 40° E., dip 85° S.E., C. B. A. Sheldon, east of four corners, strike N. 35° E., dip 85° W., S. R. H. Sheldon, east part, strike N. 35° E., dip 80° E., C. B. A. Sheldon, four corners, strike N. 35° E., dip 65° N.W., S. R. H. Sheldon, four corners, strike N. 35° E., dip 65° S.E., S. R. H. Sheldon, near four corners, strike N. 35° E., dip 75° S.E., C. B. A. Waterville, strike N. 20° E., dip 60° W., S. R. H. Waterville, south part, strike N. 25° E., dip 76° W., C. B. A. Waterville, steatite, strike N. 10°–20° W., S. R. H. Waterville, mills, dip 25° S.W., Z. T. Cambridge, west part, strike N. 35° E., dip 85° W., S. R. H. Cambridge, borough, strike N. 20° E., dip 90°, C. H. H. Cambridge, south part, strike N. 20° E., dip 90°, A. D. H. Cambridge, west part, strike N. 20° E., dip 75° E., C. B. A. Montgomery, west part, strike N. 10° E., dip variable, S. R. H. Montgomery, Enosburgh line, strike N. 35° E., dip 80° N.W., S. R. H. Montgomery, a mile west of center, strike N. 20° E., dip west, S. R. H. Richford, falls, strike N. 50° E., dip 76° W., S. R. H. Richford, village, strike N. 30° E., dip 80° W., C. H. H. Berkshire, east part, strike N. 10° E., dip 70° W., C. B. A. East Berkshire, strike N. 25° W., dip 90°, C. H. H. Berkshire, north of do., strike N. 25° W., dip 90°, C. B. A. Berkshire, north part, strike N. 20° E., dip 55° E., C. B. A. Berkshire, middle of Canada line, strike N. and S., dip east, C. B. A. Berkshire, east part, dip 60°–70° W., Z. T. Berkshire, west part, dip 70° E., Z. T. Berkshire, middle, strike N. 40° E., dip 88° E., S. R. H. and C. H. H. Berkshire, north of village, strike N. 40° E., dip 35° E., S. R. H. Berkshire, north part, strike N. and S., dip 90°, C. B. A. Berkshire, west of do., strike N. 5° E., dip 45° E., C. B. A. West Berkshire, strike N. 40° E., dip 65° E., C. H. H. and E. H. Berkshire, northwest corner, strike N. 45° E., dip 80° E., C. B. A. Franklin, northeast corner, strike N. 30° E., dip 70° E., C. B. A. Franklin, center, dip 60° E., Z. T. Franklin, middle part, strike N. 35° E., dip 50° S.E., C. B. A. Franklin, northwest of center, strike N. 45° E., dip 50° S.E., C. B. A.

We will arrange in tabular form the position of the strata and the number of axes upon the several sections.

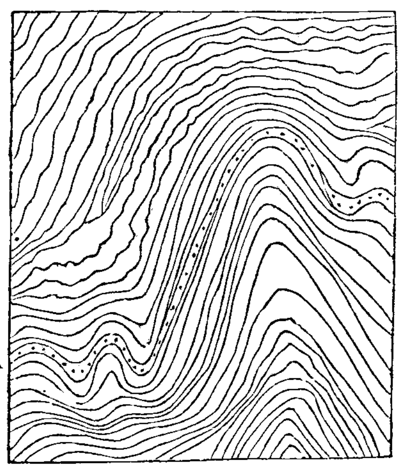
Locality.	*East Range.*	*Middle Range.*	*West Range.*
Section I,		All dip east,	
Section II,		Sharp anticlinal; east side dip 30°, west side 70° W.,	
Section III,		Two anticlinals and a synclinal,	
Section IIIa,		Two anticlinals and a synclinal,	

Locality.	*East Range.*	*Middle Range.*	*West Range.*
Section IV,		All dip east,	
Section V,		Synclinal axis,	
Section VI,	Vertical,	All dip east at various angles,	
Section VII,			
Section VIII,	Anticlinal,	At least one synclinal,	All dip east.
Section IX,	Anticlinal,	At least one synclinal,	All dip east.
Section X,			
Section Xa,			
Section XI,			
Section XII,			
Section XIII,		Synclinal,	Fan-shaped stratification.
Massachusetts Section,		All vertical,	
From Craftsbury to St. Albans,		Synclinal,	Synclinal.

There is one characteristic of the dip and strike of the strata not yet mentioned, and it is difficult to do it justice. In certain districts the strata are exceedingly contorted, and the average dip and strike are the ones that are recorded. There is not a square mile of this rock in the State where there are not more or less of these irregularities. In a few instances the difficulty of ascertaining the true position is so great that we have not attempted it.

As a general fact it may be stated that these disturbances are most marked among the Green Mountains, or in the vicinity of the gneiss. We give a single illustration of the true position of strata in a region not at all distinguished for irregularity. Fig. 276 represents a surface of twelve square feet upon a ledge of talco-micaceous schist exposed to view by a natural joint, on the east border of the middle range near Proctorsville. A, A, are two strata, two and a half inches wide, of quartz, etc. The other strata are from one-sixteenth to one-fourth of an inch in size, of talco-micaceous schist, aluminous and plumbaginous slates, and a single narrow stratum (vein?) of hyaline quartz. The strata are represented upon the list of the dip and strike as perpendicular; but the inclinations of the strata in this figure, which are an exact copy of the original, would seem to show quite a different state of things. Yet the average dip of the strata of that ledge must be nearly vertical, as recorded.

Fig. 276.



Section near Proctorsville.

This state of things suggests two important topics: *First*, do not these contortions prove that the layers that have suffered this twisting are the strata themselves, and not the bedding of cleavage or foliation? For the beds between cleavage planes are rarely contorted. The strata may be contorted while the cleavage planes cross them with perfect regularity. In fact the cleavage does not appear to have been reduced until the strata had quietly settled into their present positions, as a general thing. If cleavage results from pressure, as some maintain, it almost necessarily follows that the force has essentially ceased to be exerted after the production of the cleavage, that is, the foldings are all plicated before the cleavage is produced. With all theories it is an admitted fact that it is produced after the plication; hence the folded beds in the above figure are strata, and cleavage is wanting. The same remarks apply to foliation. If this case is that of plication of strata, then all the little undulations in the formation are the same, and we might remark still further that if the folded layers are strata, then the position we have adopted respecting the sedimentary origin of these layers must be inferred.

Secondly, the immense number of plications in the strata of talcose schist may enter into our calculations respecting the thickness of the strata. Inasmuch as the problem of the thickness of the formation is one of unusual difficulty to solve, every fact of the slightest consequence will contribute materially to the true result. If strata regarded as vertical by all geologists in these metamorphic regions are as much divided into small convolutions as the figure before us, at least one-half of the thickness calculated from observed inclinations by trigonometry may be thrown away as excess. This shows us that a considerable fraction of the whole may be disposed of, as this particular case may not occur every rod. In disturbed regions fully one-fourth of the calculated thickness may be safely left out of the account.

There is no unconformability between the talcose schist with the adjacent formations. The succession is invariably unbroken. Rarely, however, there may be a very sudden change in the position of the strata in the middle of the formation, as upon Sections X*a* and XI, in Hydepark and Wolcott, where there is nearly an abrupt change from vertical strata to layers having a very small eastern inclination.

Range, Extent and Thickness.

As already intimated, there are three great ranges of talcose schist in Vermont. The eastern, and smallest, lies partly in New Hampshire, along Connecticut River. It is the most obscure of the three. It enters Vermont in Springfield, passes out again at the Weathersfield "Bow," re-enters in the southeast part of Hartford, and continues in Vermont until it terminates near Guildhall. The middle range, which is the largest, enters Vermont from Massachusetts in the town of Halifax, and runs nearly north through the State, greatly increasing in width near Plymouth, and passing out of Vermont into Canada, in Troy and Newport. The western range, which is the widest of the three at its northern part, is nearly of the form of a wedge, having its point in Bristol (possibly further south), and being the widest at the Canada line, lying in the towns of Franklin, Berkshire and Richford. The middle and western ranges unite north of Jay Peak.

Commencing with the eastern range we will give a particular description of the rocks of this group.

North of Bellows Falls in Rockingham, there is an extensive surface between the ledges of clay slate and the gneiss in which the ledges are obscured by alluvium. Inasmuch as further to the north the talcose schist occupies a region between the slate and the gneiss or granite, we might suppose that it would occur in Rockingham without any special evidence of its presence. But in an excavation for the R. and B. R. R. just east of Rockingham Station, there is a large ledge of a beautiful talcose schist dipping 60° W. The same rock occurs again in the south part of Springfield along Connecticut River, and is exhibited in a more characteristic form than usual, namely, a soft schistose rock of a clear green color. It passes north into Weathersfield; and as the Connecticut makes an abrupt curve westward, the schist crosses the river into New Hampshire. In these three towns this rock has only been casually examined.

Its prolongation into New Hampshire we have not seen. In the northeast part of Hartland the river turns quickly to the northeast, and thus the schist enters Hartford.—A mile and a half southwest of White River Junction, the rock is an indurated talcose schist with sulphurets of iron and copper in small veins scattered through it. A porphyritic hornblende rock is found to the east of this, and veins of quartz traverse the formation. Along White River we found numerous blocks of the peculiar indurated black calcareous schist belonging to this range. There are obscure traces of stratification in it: and numerous large blotches of a black argillaceous matter, which effervesces strongly with acid, are thickly strewed through it. At White River Village a compact hornblende rock is interstratified with soft talcose slate. Analogous rocks were passed over on our way to Norwich Center. Southeast of this village there is characteristic talcose schist filled with magnetite, succeeded on the east by the calcareous indurated schists, having here, especially when slightly acted upon by the weather, a reddish tinge.

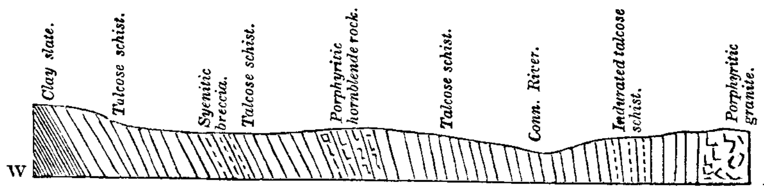
At Hanover, N. H., the rock changes to hornblende schist containing beautiful small garnets, which are much prized by mineralogists. Along the Passumpsic railroad through the whole of Norwich, there is a fine opportunity to study this rock. There is a porphyritic hornblende rock containing rutile, etc., closely resembling a rock of the same appellation in Williamsville, at some mills west of Norwich Center. In the north part of Norwich and passing over the Thetford line, is a large deposit of an impure serpentine in talcose schist; and there is steatite in Thetford upon the land of Jeduthan Taylor and Jacob Newcomb. Generally in Thetford the characteristic variety of talcose schist is present. It merges into clay slate westerly, and is talco-micaceous in its eastern part. As we proceed north, talcose schist of the common and indurated varieties are everywhere seen along the river in East Fairlee and Bradford.

South of the village of Newbury indurated talcose schist appears. East of the village at an excavation for the railroad the rock is a very fine-grained talcose slate, but not generally argillaceous. Two miles north it is soft and easily crumbles; and has been much contorted and broken by some force exerted in the alluvial period. Near the same locality the strata become thicker, take a little hornblende into their composition, and bunches of limestone appear in the crevices. Very fine dendrites are here also. In Newbury this range is more than two miles wide. North of Newbury the formation trends to the east and passes out of Vermont in the north part of Ryegate into Bath and Munroe in New Hampshire. It appears again in the northeast part of Barnet—as Vermont there begins to widen greatly its area. Associated with it there is an interesting breccia cemented by syenite, analogous to some semi-igneous rocks of the southern part of the State.

Fig. 277 represents a section of the whole of this range from Littleton, N. H., to the west part of Waterford. East of the porphyritic granite there is an immense amount of common granite. The talcose schist first seen stands upon its edges, and is both indurated and soft, with a little serpentine. The porphyritic hornblende rock is a very compact hornblende with large distinct crystals of feldspar scattered through it. It exceedingly

resembles trap rock. Thus the whole formation appears to be a sharp synclinal axis. The same general varieties of rock occur in Lunenburg and Concord.

Fig. 277.



Section through Waterford.

In this range of talcose schist in New Hampshire there are beds of limestone in the towns of Haverhill, Lisbon, Lyme, Orford, Claremont and Cornish. But one bed as yet has been found in Vermont in it, and that is upon the land of Col. White, in Lunenburgh.

In Victory there is a band of chlorite schist in the mica schist, and in Guildhall there is a band of talcose schist which we have regarded as the northern end of this range. North of these localities the rock is mica schist; and the talcose schist terminates in two prongs, as it were, which are interstratified with the mica schist. Yet we have had doubts whether the mica and talcose schists were not originally the same, but now are different through metamorphism.

The middle range of talcose schist commences in Middlefield, in Massachusetts. It continues in a due northerly course until near the Vermont line, when it makes a large curve to the east, hitherto not represented upon any map, entering the State at Halifax. The formation is mostly composed of hornblende schist, plumbaginous schist, and talco-micaceous schist for the first ten miles of its course, when talcose schist increases in amount and finally predominates. North of Halifax there is a great amount of steatite and serpentine, extending through the whole State in the form of beds, near which the talcose schist is usually characteristic. In Marlboro, beds of gneiss and hornblende schist are interstratified with the talcose schist. In Newfane, Dover, and Wardsboro, there are many interesting varieties of rock and undulations in their position, which are described upon Section III. In Jamaica, Townshend, and Windham, the formation is quite narrow but well defined, with immense deposits of serpentine, steatite, and less abundant beds of limestone. It is near the east line of Jamaica and the west line of Townshend that this range extends, and also through the central parts of Windham. In the south part of Andover, at Simonsville, at Andover Center, and all along the road from Windham to Ludlow, talcose schist may be seen.

We are beginning to find a considerable portion of limestone in this formation. There are beds of it in Jamaica and in the south part of Windham. On Mr Hutchin's farm in the west part of Andover there is a limekiln—also in the north part of the town. East of Simonsville also there is a considerable amount—and in fact, according to a well-informed citizen, there are small "bunches" of limestone upon almost every farm in Andover.

In the south part of Ludlow there is limestone near A. Adams' house; and also in the west part of the town near the house of Levi. Lawrence. The latter is doubtless connected directly with the limestone in Plymouth, where it is of large extent.

The talcose schist is well developed in Ludlow. At A. Adams' house in the south part of the town there is the whetstone variety, which may be traced northerly several miles.

Other varieties, besides the normal rock, are talcose conglomerate, near the east line, and chlorite schist. The strata are not generally contorted, but are remarkably regular.

This range of schist is divided by a deep valley, which commences in South Ludlow, and extends through Plymouth and Bridgewater, and probably through Pittsfield and the north east part of Chittenden. This valley lies nearer the western than the eastern border of the schist.

Near the line between Bridgewater and Sherburne, there are strata of plumbaginous schists, passing into clay slate. It is in these that we first recognize the narrow band of slate, extending probably from Plymouth to Troy. Other varieties of rock in Bridgewater are two beds of quartz rock, entering the town from Plymouth, two beds of steatite and gold-bearing rocks. The transition from talcose schist to gneiss, in Plymouth and Sherburne, is very gradual; insomuch that beds of the two rocks alternate near their junction. On this account it is somewhat difficult to draw the line between them on the map.

The talcose rocks in Stockbridge, Bethel, Rochester, Hancock, Braintree, Granville, Roxbury, and Warren, do not vary essentially from those described in Ludlow, Plymouth, and Bridgewater. The same rocks are associated with them also.

The following is the order of rocks in Roxbury and Bethel, going through these towns in an easterly direction:

Common talcose schist.
Bright-green talcose schist.
Chlorite schist with dolomite.
Talcose schist.
Quartz rock (village of Rochester.)
Talcose schist.
Talcose schist with beds of dark quartz.
Clay slate.
Talcose schist.
Plumbaginous and talcose schists.
Serpentine and Steatite.
Talco-micaceous schist.
Steatite and limestone.
Talcose schist.
Steatite with much iron ore, and serpentine.
Talcose schist.
Chlorite schist.
Talcose schist with dolomite.
Steatite, (Bethel village.)
Talcose schist, whitish-colored, and green.

Next follows the clay slate of another group.

If there is any talcose schist in Vermont containing magnesia, judging from the greasy feel of the rock, it should be in Roxbury, near the Verd-antique serpentine. But these are aluminous, instead of magnesian, as is clearly proved by analysis.

The character of the rocks along Winooski River, has already been described in treating of the lithological character of the talcose schist. The rocks from West Montpelier to Middlesex village, are the following, in order: Talcose schist, novaculite schist, hornblende schist, mica schist (garnetiferous), novaculite schist, talcose grit, coarse calcareous grit, talcose schist. One of the most remarkable features of the talcose schist, along its eastern border, from Montpelier to the Canada line, is the association with it either of talcose grits and conglomerates, or of conglomerate without any talcose matter. The conclusion legitimately derived from these facts (stated elsewhere in this Report in full), is that the schists may have been derived originally from sandstone or conglomerate.

In Morristown there are, besides the common talcose schists, novaculite schist, hornblende schist, and a highly ferruginous quartz rock. In Wolcott much of the schist has a peculiar appearance. It is very finely grained, perfectly homogeneous, and very compact. The divisional planes, supposed to be planes of stratification, closely resemble the divisional planes of the quartz rock west of the Green Mountains for their regularity. Its color is much lighter than that of the ordinary schists. There are also talco-micaceous and epidotic talcose schists in Wolcott.

The following is the order of rocks from Craftsbury to Johnson in this formation, between the clay slate and gneiss: Talcose schist with a few strata of quartz, novaculite schist, talcose grit, novaculite schist, talcose schist, talcose schist with beds of quartz, ferruginous quartz, hornblende schist, talcose schist, green clay slate, ordinary clay slate, talcose sandstone, talcose grit, gneissoid rock, talcose rock with silicious layers, gneissoid talcose schist, limestone, calcareous sandrock, talcose schist with pebbles of quartz and feldspar, talcose schist, argillo-talcose schist, a clay slate, talcose schist. In Johnson the strata are full of the minor contortions already described, so much so as to render impossible any judicious estimate of the strike and dip of the strata upon many ledges.

The novaculite schists have changed into exellent novaculite of economical value in Irasburgh. The same range extends to Coventry, and its relations to the adjacent rocks are given in Fig. 268. In going west from the clay slates and upper Silurian limestone of West Coventry village, the following is the order of the talcose rocks: Talcose schist, talcose sandstone and conglomerates, light-green talcose mass with little stratification, talcose schist, novaculite, talcose schist.

In the north part of Coventry the remarkable bed of conglomerate, described previously under the lithological characters of talcose schist, occurs, and is supposed to form a bed in the formation, although it is within a quarter of a mile of the clay slate. Owing to alluvial accumulations it has been impossible to trace this bed a great distance.

There is very much of the novaculite in Newport. Some of the honestones from Lake Memphremagog are well known for their excellent sharpening properties. Other varieties of rock in Newport are granite, indurated talcose schist, and epidotic talcose schist. In Troy the talcose rocks contain many small rounded pebbles. The remarkable deposits of serpentine and associated minerals in Orleans County are described elsewhere.

The widest portion of this middle range of talcose schist is between Hardwick and Mansfield Mountain. It is narrowest in Marlboro, Dover, and Newfane. North of Stockbridge it widens very suddenly. This rapid expansion may be connected with certain foldings of the strata, yet to be investigated. It seems to be connected with a range of mountains running northwesterly in Pittsfield and Chittenden, at variance with the common direction of the Green Mountain ranges.

The gneiss of the Green Mountains, which has separated the middle and west ranges of talcose schist south of Richford, is marked upon the map as terminating in Richford. Hence the two ranges unite, and turn sharply around the gneiss. Jay Peak is coarse talcose schist, according to Prof. Adams, the talc being in rather large proportion, with numerous small, irregular masses of pure chlorite, and an irregular vein of white quartz. The rock is often highly charged with crystals of magnetic iron ore, so as powerfully to affect the compass.

The western range of talcose schist commences at the south line of Lincoln. It is there very narrow. In Lincoln the rocks are talcose schists and sandstones. In Huntington they are mostly talcose schists. In the south-east corner of Huntington, there is a mass of a syenitic rock. It is a coarse highly crystalline compound of black hornblende, and greenish horn-colored feldspar. From the gneiss of Bolton to the talcose conglomerates in the north-west corner of Richmond, the following is the order of rocks:

Talcose schist with Adamsite.
Talcose gneiss.
Talcose schist.
Gneissoid talcose schist.
Talcose schist (Jonesville.)
Calcareous talcose schist.
Gneissoid rock.
Talcose schist.
Green compact hornblende schist.
Talcose schist.
Novaculite schist.
Clay slate.
Talcose conglomerates.

Prof. Zadock Thompson has the following respecting this range of rocks in Chittenden County: "Along the foot of Mansfield Mountain in Underhill, a thick-bedded mica slate occurs, which makes a very good building stone. The stratification is so completely obliterated, that much of it, like granite, splits in all directions with nearly equal facility. In connection with these beds, seams of chlorite frequently occur. Some of the strata ranging north and south through Underhill, Jericho, Bolton, and Huntington, are of a ferruginous character, and iron ore in small quantities have been found in several places, but not enough to justify the expectation of finding it in quantity. Near this range of ferruginous slate, a narrow range of plumbaginous slate shows itself in several places, as in Huntington, Bolton and Jericho. This is doubtless a continuation of the same narrow range of plumbaginous slate, which occurs in Cambridge, Waterville, and the western part of Montgomery and Richford.

"To the eastward of the synclinal axis passing through Underhill, and the eastern part of Jericho, the rock perhaps should be called mica slate, although it usually contains more or less talc. The rocks on the summit of Mansfield Mountain appear in places, at least, to be talcose slate. A great part of the slate which forms the mountains extending from the chin towards the north along the eastern border of the county, abounds in octahedral crystals of magnetic iron."

The following are the rocks belonging to the talcose schist in Cambridge, beginning at the eastern border: Talcose gneiss, feldspathic talcose schist, talcose gneiss, talcose schist containing crystals of magnetite and feldspar, novaculite schist, quartzose grit, plumbaginous shales, whetstone talcose schist, talcose grit, gneiss, talcose schist, talcose sandstones and talcose conglomerates in great amount.

Upon Section XII, the west range of talcose schist is wider than upon any other section. The rocks are mostly talcose schists and grits, with a few sandstones and novaculite schists. There is very much hematite in the town of Fairfield in this rock.

The rocks along the northern line of the State from Richford to Franklin are these: feldspathic talcose schist, talcose schist, talcose grit, talcose schist, talco-micaceous schist, talcose grit, talcose schists with hematite and geodic masses, talcose schist, epidotic talcose schist, talcose schist, and novaculite schist. The epidotic schists are the most remarkable and unusual of all these varieties. It is found over an area from two to four miles wide and eight miles long, in Berkshire and Enosburgh. It is probably doubled by a fold of the strata. We cannot state the facts concerning the distribution of the

talcose schist north of Section XI, upon the western range, because we have been obliged to use second hand statements in part: and what was personally investigated was not thoroughly explored.

MINERALS IN TALCOSE SCHIST.

BY E. HITCHCOCK, JR.

Native Gold. This valuable, and inoxydizing metal crystallizes (rarely) in octahedra and dodecahedrons. Primary form, the cube. In composition it is usually found to contain a large proportion of silver and some copper. The California gold averages eight hundred and seventy-five to eight hundred and eighty-five thousandths in gold, and the Australian gold nine hundred and sixty to nine hundred and sixty-six thousandths. It is most usually obtained from alluvial washings, but sometimes it is extracted from rocks by crushing them, and dissolving out the gold by mercury.

The practical details of the working, value, and amount of gold in Vermont will be described by Mr. Hager, under the section devoted to Economical Geology.

Specimens have been found in the following towns: Searsburgh, Somerset, Bennington, Shaftsbury, Arlington, Sandgate, Manchester, Dorset, Danby, Mount Tabor, Marlboro, Newfane, Dover, Wardsboro, Jamaica, Townshend, Windham, Athens, Andover, Chester, Grafton, Cavendish, Ludlow, Plymouth, Bridgewater, Barnard, Bethel, Royalton, Stockbridge, Pittsfield, Rochester, Hancock, Braintree, Randolph, Roxbury, Warren, Northfield, Waitsfield, Warren, Fayston, Duxbury, Moretown, Berlin, Middlesex, Montpelier, Worcester, Waterbury, Stowe, Eden, Johnson, Cambridge, Waterville, Belvidere, Lowell, Westfield, Troy.

It may be seen in the State Cabinet, under Nos. 1 to 4, inclusive.

Serpentine. It was formerly supposed that this mineral crystallized in right rectangular prisms, but it has subsequently been shown that these were pseudomorphs. As usually found, it is a massive mineral of various shades of green, forming a handsome ornamental rock, and some of the Vermont varieties particularly so. In composition it is essentially a hydrous silicate of magnesia and iron. An analysis of a Vermont serpentine, made several years ago by Dr. C. T. Jackson, gave the following results:

Water,	7.70
Silica,	45.80
Magnetic Iron,	2.00
Magnesia,	33.44
Protoxyd of Iron,	7.60
Oxyd of Chrome,	2.00
Loss,	1.46
	100.00

This mineral has been found in Vermont at Troy, Gay, Lowell, Westfield, Baltimore, Cavendish, Newfane, Thetford, Newbury, Middlesex, Moretown, Northfield, Roxbury, Warren, Waterbury, Sterling, Waterville, and in many other places.

Specimens may be seen under Nos. 315–16–17, in the Mineralogical Collection, and in larger quantities among the rocks.

Picrosmine. This mineral is regarded by Prof. Shepard as pseudomorphic when found in the crystalline form. Prof. Dana, however, considers it as belonging to the trimetric system. It is a hydrated silicate of magnesia, containing iron and alumina. Generally it is fibrous in structure, but often it is cleaveable and massive. In color it is greenish-white, also dark-green. Luster pearly, inclining to vitreous. The fibrous variety resembles asbestus. It is found in Vermont at Roxbury, Jay, Lowell, and South Troy. In the Cabinet it is numbered 312–13–14 inclusive.

Magnetic Iron. (Described under Calciferous Mica Schist.)

Emerald Nickel. Emerald nickel is never found crystallized, but in mammillary crusts, and sometimes botryoidal or stalactitic. It is of emerald-green color, as its name implies, and is a hydrated carbonate of nickel. It was discovered a few years since by Prof. B. Silliman, jr., and at present there are very few localities where it is found. In Vermont it has been discovered at South Troy, and can be seen in the State Collection under Nos. 368–9.

The minerals found in this formation are Native Gold, Serpentine, Picrosmine, Magnetic Iron, Emerald Nickel, Garnet, Pyrites, Rutile in Quartz, Rhomb Spar, Calcite, Dolomite, Bitter Spar, Micaceous Iron Ore, Actinolite, Chlorite, Chrysoprase, Drusy Quartz, Quartz Crystals, Pyroxene, Orthoclase, Tourmaline, Chromic Iron, Asbestus, Talc including Steatite, Native Copper, Galena, Blende, Blue Spinel, Chalcopyrite, Graphite, Chalybite, Specular Iron, Anthophyllite, Rhodonite, Pyrolusite, Mispickel, Hornblende, Chrysolite (in basaltic dike), Epidote, Brucite, Red Hematite, Heavy Spar, Amianthus, Wad, Psilomelane, Raphilite, Pyrope, Natrolite, Pimelite.

Garnet. (Described under Calciferous Mica Schist.)

Pyrites. (Described under Calciferous Mica Schist.)

Rutile. The general description of this mineral has already been given, but the peculiar varieties found in the talcose schist demand a special description. The one to be here described is the rutilated quartz of Waterbury, Vt. This is simply clean crystals of quartz containing capillary or hair-like crystals of rutile. In some instances these capillary crystals radiate from a common center, while at other times they are promiscuously scattered through the quartz. Erratic bowlders containing these crystals have been found in Waterbury, Vt. and in some of the adjoining towns, as well as in New Hampshire. But their original position was not known till the construction of the Vermont Central Railroad. During the building of this railway at a rock cutting in Waterbury, a vein of quartz was met in the talcose slate which contained this rutile. The quartz containing the rutile was mostly in cavities or druses, and was either limpid or brownish-yellow, somewhat like the Irish cairngorm. The rutile is of a reddish-brown with a luster like that of burnished copper, resembling red hair—so much so that it has been provincially termed *Venus hair-stone.* Some of them, however, are entirely black, resembling tourmaline. It is much to be regretted that this locality is entirely exhausted, and that the specimens being of so great a value have all been secured, so that it is impossible fully to illustrate this beautiful feature of Vermont Mineralogy in the State Cabinet, although Nos. 99 and 100 are specimens from the Waterbury vein.

Rhomb Spar. Rhombohedral, a variety of dolomite. A chemical analysis of a specimen from Roxbury, Vt., by T. S. Hunt, gave carbonate of lime 53.90, carbonate of magnesia 44.04, carbonate of iron 3.05.—"Rhomb Spar and Bitter Spar are names applied to crystallized varieties (generally imbedded crystals) provided their faces are not curvilinear or pearly; also to large grained and easily cleavable varieties of a light color." It has been found in Vermont at Roxbury, Middlebury, Grafton, Jamaica, Newfane, Norwich, Bethel, Bridgewater, Cavendish, Chester, Athens, Jay and Lowell. It is numbered in the State Cabinet from 351 to 364 inclusive.

Calcite. (Described under Calcareous Mica Schist.)

Dolomite. (Described above under Rhomb Spar.)

Bitter Spar. (Described above under Rhomb Spar.)

Micaceous Iron Ore. This is only a variety of the hematite, where the lamellæ are brilliant like a speculum. It is an abundant variety of iron ore occurring at Weathersfield and Plymouth. Nos. 67 and 68 are specimens of micaceous iron from Weathersfield, Vt.

Actinolite. (Described under Calciferous Mica Schist.)

Chlorite. This in the massive state is of a leek or blackish-green, but when crystallized dull emerald-green. Its primary form is that of a rhomboid. Sometimes it assumes a vermicular form. Its composition is a hydrated silicate of alumina, magnesia and iron. One variety of chlorite called Leuchtenbergite is white. It is a very common mineral everywhere. In Vermont it has been found at Belvidere, Newbury, Mount Holly, Marlboro, Grafton, Bethel, Bridgewater, Chester, Reading and Lowell.

Chrysoprase. This is merely a variety of quartz or chalcedony colored green by nickel. This has probably been found at Newfane, though no chemical examination of it has yet been made.

Drusy Quartz. This, too, is merely quartz in very minute crystals, usually found as a lining to cavities. This occurs at Newfane and Halifax. It may be seen in the Cabinet under the Nos. 153 to 156 inclusive.

Pyroxene, Orthoclase and *Tourmaline*, are described under Calcareous Mica Schist.

Chromic Iron, or *Chromite.* This crystallizes in the monometric system and is generally found as an octahedron. Color between iron and brownish-black and is sometimes magnetic. In composition it is composed of protoxyd of iron, sesquoxyd of chromicum, alumina, magnesia and a trace of silica and protoxyd manganese in some specimens. One of the best localities in this country is at Baltimore, Md., where it is mined to the extent of 1000 tons annually for the purpose of procuring the oxyd of chrome which is used in painting on porcelain and with oil. It is found mostly in serpentine, and is the essential coloring matter in Verd-antique marble. It occurs in Vermont at Troy, Jay, Westfield, Newfane and Roxbury. No. 66 in the Collection is a specimen from Jay, Vt.

Asbestus. This fibrous mineral has already been partially described under Mountain Leather. The name is derived from the Greek signifying unextinguished, since it was used as wicking by the ancients for their lamps, which kept continually burning in the temples. It is a fibrous variety of tremolite or actinolite. The fibers are as fine as flax, and may easily be separated by the fingers. The color is usually white or nearly so. In Lowell, Vt., it is found in considerable quantity, lying loosely in the soil: the containing rock being entirely decomposed. One use of this mineral is to pack the air chambers of salamander safes. It is also said that it has been woven into a coarse cloth, which is fire proof. This is done by "mixing the fibers with flax, carding, spinning, and weaving the compound, and then burning out the vegetable constituent by exposing the goods to fire." It has been found in Vermont at Lowell, Troy, Jay, Weybridge, Swanton, Cavendish, Chester, Roxbury, Mount Holly and Newfane. Specimens of it in the Cabinet, may be seen from Nos. 206 to 225 inclusive.

Talc and Steatite. According to Prof. Shepard, it crystallizes in right rhombic prisms. In chemical composition it is a hydrous silicate of magnesia, with traces of iron and alumina in some specimens. It is the essential ingredient in steatite or soapstone, and in talcose schists. In color it varies from white to green of various shades. Talc has a greasy feel, and in hardness is marked 1.00 or the softest mineral on the scale of hardness. Talc, especially in the form of steatite or soapstone, resists the most powerful heat, and retains heat the longest of any known substance. Its uses however will be described in another part of this Report. Talc and soapstone have been discovered in Vermont, at a great many places: among the many, may be mentioned Thetford, Braintree, Moretown, Roxbury, Waterbury, Belvidere, Johnson, Sterling, Waterville, Stow, Enosburgh, Richford, Windham, Grafton, Marlboro, Newfane, Arlington, Bethel, Bridgewater, Cavendish, Chester, Norwich, Rochester, Baltimore, Athens, Troy, Jay, Lowell, Westfield, Norwich. Specimens of talc and soapstone are to be found in the Cabinet, from Nos. 298 to 311 inclusive.

Native Copper and Galena. (Described under Calciferous Mica Schist.)

Blende is sulphuret of zinc with a small percentage of iron in some specimens. Its primary form is the cube, though it is found in tetrahedrons, octahedrons and dodecahedrons. Its prevalent color is the red-brown, and it is often associated with ores of lead and silver. It is a very abundant mineral. In Vermont it has been found in Bridgewater and Thetford. In the State Collection it may be seen under the Nos. 15, 16, 17, 18 and 19.

Blue Spinel or *Automolite.* This mineral is a zinc spinel, with color black, bluish-black, and grass-green. The primary form is a cube, but it occurs as a regular octahedron with various modifications. The constituents are alumina, 55.14; magnesia, 5.25; oxyd of zinc, 30.02; peroxyd of iron, 5.85; silica, 3.84. This occurs in Vermont at Bridgewater, and may be seen in the Cabinet under Nos. 50 to 53 inclusive.

Chalcopyrite and Graphite (already described.)

Chalybite or Spathic Iron. This is principally a carbonate of iron. An analysis of this ore from Plymouth, Vt., gave carbonate of iron, 74.28; carbonate of magnesia, 16.40; carbonate of Manganese, 6.56; oxyd of iron, 0.30; and undecided, 1.40. It crystallizes in rhombohedra, which are sometimes curiously curved. In color it is very various, from ash, gray, brown, green and red, to white. It is one of the most valuable ores of iron, being one of the principal ones from which steel is made. Hence the name chalybite. It has been found in Vermont at Plymouth, Lowell, Troy, Swanton, Huntington, Guilford, Norwich, Bennington, Putney, Highgate, Chittenden and Sherburne. In the State Cabinet specimens of it may be seen under Nos. 363 to 366 inclusive.

Specular Iron is but a variety of hematite, and is described above under micaceous iron ore. The celebrated Iron Mountain, and Pilot Knob of Missouri, are composed of this ore. It is found in Vermont at Chittenden, Milton, Enosburgh and Plymouth. In the State Cabinet it can be found under Nos. 62, 63 and 64.

Anthophyllite. A variety of hornblende in long, slender, clove-brown crystals, somewhat radiating. Found in Plymouth and Grafton, and may be seen in the Collection, under Nos. 197 and 198.

Rhodonite, Manganese Spar or *Bisilicate of Manganese,* is composed of silica, oxyd of manganese, a little lime, and in a few specimens a trace of magnesia and iron. Its primary form is an oblique rhombic prism. Generally it is found massive, of a pink or rose-red color, sometimes dull brown. It is sometimes cut by the lapidary and used for inlaid work. It has been found in Vermont at Topsham, Coventry and Irasburgh.

Pyrolusite, Mispickel and Hornblende, have been described under Calciferous Mica Schist.

Chrysolite. This is generally found in grains in volcanic rocks, but its primary crystalline form is a right rectangular prism. It is of a light-green color, generally very brittle, and is found in very small masses.—Its composition is a silicate of magnesia, iron, alumina and manganese. The specimens found in Vermont were discovered at Thetford, Norwich and Cavendish Falls. It may be seen in the Cabinet under Nos. 254 and 255.

Epidote. (Described under Calciferous Mica Schist.)

Brucite. A small quantity of a mineral, apparently brucite, has been found at Roxbury. But as no chemical analysis has been made of it, it is not fair to speak with certainty concerning its occurrence there simply from its physical characters.

Red Hematite, has been described under Specular and Micaceous Iron.

Heavy Spar, or *Sulphate of Baryta.* Occasionally containing a little silica, oxyd of iron and alumina as impurities. Celestine is also a common impurity. Its primary form is that of a right rhombic prism. The prevailing color is white. One crystal (tabular) was found at Dufton, England, a few years since, weighing forty-two pounds, which was perfectly transparent. Barytes is used as a pigment when ground to a powder. It is used either alone or adulterated with white lead to the extent of 25 to 33 per cent. It is of some use as a pigment on surfaces exposed to sulphureted hydrogen, since it does not turn black. It has been found in Richford, Vt.

Amianthus. (See Asbestus above.) Amianthus has been found in Vermont at Troy, Jay, Lowell and Weybridge. Specimens 219, 220 and 221 in the Cabinet represent this mineral.

Wad. (Described under Calciferous Mica Schist.)

Kerolite. This occurs not in crystalline forms but in mammillary or botryoidal incrustations or seams in serpentine. It is white with an occasional tinge of yellow or green. Its composition is water, silica, magnesia and occasionally oxyd of iron and alumina. It is also known as Deweylite. It has been found at Lowell, Vt.

Psilomelane. (Described under Calciferous Mica Schist.)

Raphilite. A variety of hornblende. In the language of Prof. Dana "an asbestiform tremolite." Prof. Shepard describes it as consisting of "grayish or bluish-white, long, radiating, fibrous mass, of high luster, and graduating into common sahlite. It has been found in Vermont at Waterford, in a bowlder. Perhaps it came from Lanark and Perth, Canada, where it has previously been discovered. It is No. 204 in the State Collection.

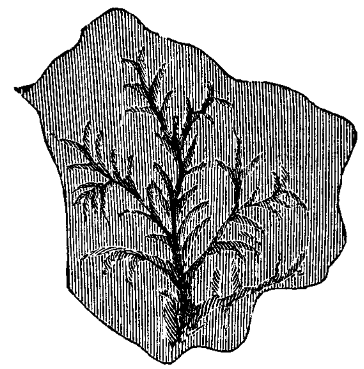
Pyrope. This mineral is regarded by Prof. Dana as a separate species, but by Prof. Shepard as simply a variety of garnet. At least the differences are slight. It has been found at Rockingham, and can be seen in the Cabinet under the Nos. 251 and 252.

Natrolite. A specimen of what seems to be natrolite has been found at Newfane, and may be seen in the Collection No. 322. A more thorough investigation and a further collection of specimens are necessary to verify the species.

Pimelite. This is an earthy mineral (sometimes massive), "occurring disseminated and in coatings; often prehemlent. Fades somewhat on exposure to air and light. Composed essentially of silicate of nickel. Found at Newfane, of which specimens may be seen in the Cabinet under Nos. 325 and 326.

Fig. 278 represents a specimen of a dendrite from the talcose schist in Newbury. It consists of small crystalline particles arranged by molecular forces in aborescent forms.

Fig. 278.



Dendrite.

*Geological Position, Equivalency, Origin and Metamorphism.**

Under clay slate we have stated, that judging from our Sections across Vermont, we must infer, almost without exception, that talcose schist lies above clay slate, and is consequently a newer rock. Moreover we have made it probable, that some of the latter must be as new as the Devonian period. True, our dips on the sections are those of cleavage and foliation: but we have reason to think that those in Vermont generally coincide with stratification, so that as the evidence now stands, and leaving out the idea of inverted dips, talcose schist is the newest of the Vermont rocks.

Again, we have evidence in many places, that talcoid and even talcose schist may be derived, by metamorphosis, from clay slate. All along the western part of Vermont and of Massachusetts, our talcoid schist, which is the magnesian slate of Emmons, passes insensibly into clay slate, and on the other hand into rock which cannot be distinguished by external characters from the most genuine talcose schist; and since the chemical characters of this rock fail to identify it, we are obliged to rely wholly on its lithological characters. Every geologist can easily recognize this rock in most cases, nor will he doubt that it may be a result of a metamorphosis of clay slate. For it is not alone along the western side of the State, that he witnesses the intermixtures of these rocks above described, but also in the bands of clay slate along Connecticut River. Novaculite, such as occurs in Guilford, is really nothing but a variety of talcose or talcoid schist. And this on the other side becomes clay slate. So in Springfield we have seen the most genuine talcose schist interfoliated with clay slate.

If, as was formerly supposed, it was necessary to have a large amount of magnesia to form talcose schist, we should not find it in clay slate. But it contains enough of this ingredient to satisfy Mr. Barkers' analyses of the talcose schist, the talcoid slate, and the novaculite of Vermont. The other ingredients could all have come from the clay slate.

We do not maintain that all the talcose schist of Vermont is metamorphosed clay slate. For we have shown how in some cases it has been derived from coarse conglomerate. A considerable part of it, indeed, contains small pebbles, or grains mechanically rounded, and no such rock could have come from slate.

The changes which take place in talcose schist on the line of strike, are quite remarkable; but they will be more conveniently described under gneiss.

The preceding theoretical conclusions are simply such as have been suggested by looking at the rocks of Vermont alone. Very probably could we study those of Canada, different results might have been reached. Indeed we believe the present opinion of the Canada geologists is, that the talcose schist is the equivalent of the newly discovered Quebec group. To such a view we have no objection, if sustained by adequate proof,—which we presume will be furnished when the results of the Canada Survey shall be made

*By E. Hitchcock, Senior.

public. Till then we rest in the conclusions to which our more limited field has conducted us.

ORIGIN OF GOLD.

Since gold occurs chiefly in talcose schist in Vermont, as in other parts of the world, this is the place to say something of its origin. It is a question which every reflecting man is ready to put to the geologist, but not one of the easiest to answer, nor one on which there is perfect agreement. The inquiry as to its localities and amount in Vermont, will be met by the Report on Economical Geology. But the theories as to its origin demand attention under the scientific head.

"Gold occurs in lodes (veins) of quartz, brown hematite and iron pyrites; in clay slate, graywacke, mica slate, hornblende slate; in granite, gneiss, syenite, quartzose porphyry, gabbro, diorite, diabase, aphanite, serpentine, and dolomite; in the gravel and sand of rivers as nuggets, laminæ and dust, generally accompanied by quartz, brown hematite, zircon, magnetic oxyd of iron, iserine, spinel, &c." (Bischof.)

But though this metal has been found more or less in so many rocks, its principal deposit all over the world is in metamorphosed Silurian, Devonian and carboniferous schists, frequently near their junction with eruptive rocks. Altered Silurian rocks are probably its most frequent position, and the quartz veins, traversing these, its immediate matrix. It is such veins traversing talcose schist that affords gold in the Ural Mountains, Australia, California, and along the Appalachian Mountains of the United States. Gold occurs, also, in the schist itself, and this not unfrequently becomes decided mica schist.

It is in the talcose schist chiefly that gold is found in Vermont, and by looking at the space covered by that rock on our Map, we can see the probable limits of any profitable explorations of that metal. It is found, however, in some quantity in gneiss, as at Bridgewater, and on Danby Mountain in the region of talcoid slate and limestone. But generally it is in superficial deposits of coarse sand, gravel and bowlders, lying above the talcose schist formation, that any quantity worth working has been found. In Bridgewater, indeed, a vein, or more probably a bed of quartz in gneiss, has been explored, and a small quantity of gold obtained from it: but not enough to yield any profits. And with few exceptions, this has been found to be the case the world over. In all the Ural Mountains, only one quartz vein has been found rich enough to repay the expense of working, though it is thought, and often asserted, that the case is different in California. But for the most part nature has collected the gold in the clay, sand and gravel of the low grounds, and there it is most easily obtained.

We are not certain of the existence of gold in the rocks, in any other than a metallic state. It occurs, however, in minute quantities in galena, and in copper and iron pyrites, and it is probable that it exists in them in the state of sulphides. In such a case, the oxydation of the sulphide would eliminate the gold, and water would remove it and throw it into the form of alluvial deposits: but to this point we shall recur again.

But little gold has been found in the secondary and tertiary rocks, although the materials of which they are composed were obtained by erosion of the palæozoic or metamorphic rocks. Hence Sir Roderick Murchison infers that the gold could not have been introduced into the palæozoic schists, till after the deposition of the secondary and tertiary rocks. He finds, moreover, that in Russia, over an area larger than half Europe, the palæozoic rocks are not crystalline and only slightly solidified, and that they contain no gold: whereas the same strata in the Ural chain, broken up and pierced by eruptive rocks, and rendered crystalline, becomes highly metalliferous and auriferous. He thinks the gold was not introduced till after the tertiary period, and he suggests that the same may be true of all the great gold deposits on the globe.

The facts adduced by Sir Roderick certainly make it very probable that gold was not introduced into the Russian rocks, till the time of their metamorphism, which he would make more recent than the tertiary. Probably it was metamorphism that introduced this metal into other strata: but the period of metamorphism may have varied a good deal, in different parts of the world. We have no means of determining the period in Vermont, only that it was probably more recent than the carboniferous period.

But the most difficult point to settle is the manner in which the gold has been introduced into the rocks. It could not of course have been introduced in its metallic state, unless it were converted into vapor. And some have indeed imagined it to have been sublimated from the intensely heated interior. But how that would disseminate it through quartz in grains too small for the naked eye, or on the other hand cause it to collect in nuggets of forty or fifty pounds, is beyond our conception. It has been more plausibly suggested, that the quartz veins containing the gold were injected from a molten mass beneath, through which the metal was diffused. But the idea of bringing pure quartz into a molten state in the earth, is absurd, since the most intense heat scarcely melts it at all. Moreover, if we could in this way introduce the gold into the veins, yet this would not carry it into the folia of the schists, where often it is found in large quantities. In short, we can conceive of no mode in which dry heat alone could bring up gold from the melted interior, and disseminate it through the rocks in a metallic state.

On the other hand there are difficulties in the hypothesis which would introduce it in the wet way. The chief one is, that we do not find in nature any compound of gold that is soluble in water. The brief remarks of Bischof on this subject, however, have a good deal of weight in them. He says, "the occurrence of gold as small crystals, and as capillary masses, is indicative of processes of reduction from compounds; and its frequent occurrence in quartz indicates the deposition of such gold compounds; from the water that deposited the quartz. There seems to be an intimate connection between gold and iron, either in the state of sulphide or oxyd, and likewise between quartz and gold. A silicate of gold may be prepared artificially, and it appears that under certain circumstances it may be dissolved in considerable amount. The silica constituting the quartz associated with gold, certainly originates from the decomposition of silicates in rocks, and it may be conjectured that the gold has the same origin possibly existing as silicate."

We hope our friend Dr. Homer Holland, of Westfield in Massachusetts, will excuse us for making some extracts, on this subject, from private letters. Coming from one so well known for his thorough chemical knowledge, and who has had such extensive opportunities for examining gold regions, we feel as if his opinions were of more importance than our suggestions, especially as some of them have an important bearing upon the auriferous deposits of Vermont.

"Our present knowledge of the chemistry of geology, and physiology of veins, is so limited and imperfect," says Dr. H., "that I shall not indulge in any speculations further than to say, that I believe that gold originally was and is secreted from a chloride, double of sodium or its sodium sulphides, together with any and all other metalliferous arsenides, sulphurides and tellurides; and, contrary to Murchison, that it is not known it was of any particular epoch, or period, especially the Silurian; and in the face of every metallurgist, from Lampadius to Phillips, that gold occurs "mineralozed," (using Van Borm's term,) by arsenic, sulphur and tellurium; and is, at the present day, in the persistent true veins of every other metalliferous sulphide, combined with sulphur.

" Every sulphide does not contain gold, it is true, but all persistent veins that ever did, in the magnesian strata, still contain it, from New Brunswick and Canada to Alabama, as I have found for the last nine years. There is denudation, geologically speaking, at Point la Tete, N. B., Chaudiere mine, of Canada, in the gold counties in Maine, and especially at the Bridgewater Vt., gold mine, as well as in Virginia, and North and South Carolina. Yet still gold occurs in all the veins in variable quantities, but enough generally, when its metallurgy is and shall be truly apprehended and legitimately in operation." Aug. 29, 1859.

"The 'bluish chloritic talc' is doubtless the absolute original repository of gold in this and every other country."

"This matrix, be it what it may prove chemically in its composition and affinities, is not talc, nor exactly agalmatolite: it is mutating in this region, in all veins at ninety feet permeated by vapor and water, and I have invariably noticed that when powdered, and mixed, and ignited with nitrate of soda, that it becomes shining, stained mica, and carries in many instances astonishing quantities of gold, resolved by this ignition, when not a particle of gold or crystalline sulphide is to be detected by the eye aided by the microscope."

"Gold may have permeated this matrix as a double chloride, or sulphide, either in vapor or solution. But when or where it came from, and was secreted, combined, or diffused and precipitated, and is now by decomposition metallized—the chemistry of geology and the inorganic physiology of veins, must settle." Dec. 26, 1859.

Dr. Holland has invented a new and ingenious method of separating gold from the sulphides, which I was anxious to have applied to those of Vermont. The following extract will show his willingness to do this, whenever he should return from the South. This very desirable work we have not attempted, because no means have been placed at our disposal for chemical investigations. But we give the extract below, to show where this process can be satisfactorily performed, should it be wished:

"I should be very glad of the opportunity of testing the Vermont sulphides for you for gold, as I know they are auriferous as well as argentiferous, in their iron, lead and zinc.

"When at Ludlow, Vt., I was very much surprised to find some very fine specimens of sulphides of copper, collected from the summit of Mount Holly near; but I had not then leisure to visit the locality (1852); besides I was not then aware that all reformed cupreous ores and sulphides, are more or less auriferous. The ores and sulphides I saw are similar to the Brazilian ores in the Patent Office (1856) collected by our naval exploring expedition, and to the Chilian, Peruvian, Carolinian and Georgian auriferous pyrites."

Upon the whole, we feel as if the introduction of gold into the rocks in the wet way, were the only hypothesis that will bear examination. But whence it originated, and why it should have selected talcose schist as its most common repository, we are unable to say. In some counties, its introduction seems to have been connected with eruptive rocks. But in Vermont no other formation is so free from igneous rocks, as talcose schist. It has indeed experienced great metamorphisms: but this seems to have been effected by hot water, rather than the dry heat of eruptive rocks. We are inclined, therefore, to say, from this and a multitude of similar facts, that the introduction of gold seems to have been connected with metamorphism, rather than the dry heat of volcanic outbursts.

As to the amount of gold that may be expected to be found in Vermont, theory furnishes no means of judging. We can only say, that a real gold formation of great extent occurs in the State, extending in fact through its whole length, and that in numerous places it yields gold, sometimes we are told in profitable amount. But practical miners are the only men who can find out where such diggings will pay. Like all other gold formations, some spots will be found rich and others poor. We trust that too much is known on this subject at the present day, to leave any to indulge in extravagant speculations, or to make investments without reason.

STEATITE AND SERPENTINE.

BY C. H. HITCHCOCK.

Steatite and Serpentine are found in beds both in the talcose schist and gneiss. They may be regarded as varieties of the two formations, but are described separately from those formations, on account of their theoretical importance. We describe them together, because of their ultimate association with each other.

Lithological Characters.

In general steatite is an impure talc, or hydrated silicate of magnesia, having the normal composition of silica, 62.14; magnesia, 32.92; water, 4.94. It is coarse-gray, grayish-green, and sometimes of quite a bright-green color. It may be granular, compact or lamellar. Its characteristic property is a greasy feel, whence its common name, soapstone. It is never known in the form of crystals. Its impurities are an excess of any of the normal component parts, peroxyd of iron, alumina, lime, oxyd of nickel, etc.

Serpentine or ophiolite, as a mineral species, is essentially a hydrous silicate of magnesia, having the normal composition of silica, 43.7; magnesia, 43.3; water, 13.0. Protoxyd of iron sometimes replaces a portion of the magnesia. The impurities are generally the same as in steatite. Serpentine has been found in crystals, precisely like those of chrysolite, belonging to the trimetric system, but it is possible that they are only pseudomorphs. The hardness of serpentine is from 3 to 4, rarely 5. Specific gravity 2.507—2.591; some fibrous varieties being as low as 2.2—2.3.

The luster varies from resinous to greasy. The color is leek-green and blackish-green; and varies to nearly white. It becomes yellowish-gray on exposure. The streak is white, slightly shining. It is generally opaque, but fine specimens are translucent. The fracture is conchoidal or splintery. It is sectile, i. e. fragments of it may be separated from large specimens, by a knife, without falling to powder, but they will pulverize under repeated blows of the hammer.

It is not in every bed of serpentine that the pure mineral is to be found. It may be associated with foreign minerals, such as actinolite, hornblende, diallage, quartz, calcite, dolomite or carbonate of magnesia. Hence, according to the abundance of the associated mineral, the serpentine may be called calcareous, dolomitic, magnesitic, hornblendic, diallagic, or chromiferous. Nor is the structure uniform. It may be compact, granular or gneissoid. A still more curious structure is when the serpentine is a cement for breccias and conglomerates, or when both the fragments and cement are of serpentine.

The following are the prominent varieties of these magnesian rocks in Vermont:

1. Common steatite.
2. Calcareous steatite.
3. Green steatite or chlorite.
4. Compact serpentine.
5. Serpentine and Talc.
6. Verd-antique serpentine.
7. Actinolite rock.
8. Hornblende rock.

The common steatite may be found at every soapstone bed in the State. When it is connected in any way with limestone or dolomite, the steatite often takes some of the carbonate into its composition, and effervesces when acid is placed upon it; though its calcareous character would not have been suspected.—Such is the steatite at Levi Lawrence's, in Ludlow.

It is much more common to find the steatite of a decidedly green color and fibrous aspect, like chlorite. It is foliated talc. Indeed some of the best steatite in the State is of this description. Localities of it are at Rochester, Marlboro and Bethel.

The compact serpentine embraces two minor varieties,—the common opaque serpentine, and the translucent, delicate-green, precious serpentine. In compactness there is great variety, though not so much in hardness. Some specimens break with great difficulty, others yield quickly to the hammer. The latter varieties are the ones that are most valuable for ornamental purposes.

As the steatite and serpentine are so often associated together, it is not surprizing that many large masses should be a mixture of the two minerals. Such is the mixture of serpentine and talc. The talc may be either foliated, or be present in its impure form of steatite. Suites of specimens may be obtained at such a bed as that in Newfane, which will embrace every possible variety between steatite and serpentine.

Verd-antique serpentine is a beautiful mixture of serpentine, dolomite, and sometimes chlorite and talc. It may be a brecciated mass, and the spaces will be filled with dolomite, and crystals of other minerals.—The name is given from its resemblance to the rich, dark Verd-antique porphyry of the ancients. It is found in Vermont at Roxbury and Proctorsville.

Actinolite is so common in many localities, that the mass may appropriately be called actinolite rock. It consists of a mixture of actinolite and talc, and passes both into serpentine and into hornblende rock.—The latter is mostly pure hornblende without admixture with any other mineral. It is massive, and yet has a crystalline structure. It is of a black color, with a greenish tinge. It is conspicuous on account of its curious developments. It occurs in large nodular-like masses, often suddenly disappearing, and then as quickly reappearing. In Grafton and Moretown are good examples of this rock.

Other minerals associated with these magnesian rocks, but not in sufficient amount to form rocks, are asbestus, massive garnet, compact feldspar, carbonate of magnesia, magnetic iron or native magnet, chromic iron, green and white talc, brucite, diallage, calcite, dolomite, quartz, picrosmine, emerald nickel, brown or bitter spar, magnetite.

BEDS OF STEATITE AND SERPENTINE.

There are at least sixty beds of steatite in Vermont, and they are in the following towns: Readsboro, Marlboro, Newfane, Windham, Townshend, Athens, Grafton, Andover, Chester, Cavendish, Baltimore, Ludlow, Plymouth, Bridgewater, Thetford, Bethel, Rochester, Warren, Braintree, Waitsfield, Moretown,

Duxbury, Waterbury, Bolton, Stow, Cambridge, Waterville, Berkshire, Eden, Lowell, Belvidere, Johnson, Enosburgh, Westfield, Richford, Troy and Jay.

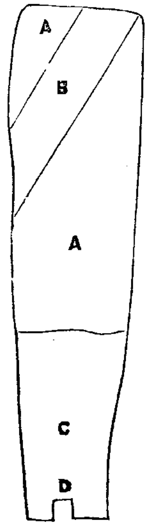
There are at least twenty-five beds of serpentine in Vermont, and they are located in the following towns: Dover, Newfane, Windham, Ludlow, Cavendish, Norwich, Roxbury, Warren, Waitsfield, Moretown, Middlesex, Waterbury, Northfield, Hazen's Notch in Westfield, Waterville, Montgomery, Richford, Lowell, Westfield, Troy and Jay. We will first describe the beds of steatite and then those of serpentine.

BEDS OF STEATITE.

Commencing at the southern part of the State and proceeding northward, there is said to be a bed of steatite in the town of Readsboro. Our authority for the existence of this bed is Dana's Mineralogy, fourth edition, Part II, page 479. It is situated in gneiss; and there are said to be very good specimens of glassy actinolite associated with it. It is not very common to find beds of steatite in this belt of gneiss which embraces the Green Mountains. Yet it is found in this formation, in Bolton and perhaps in Cambridge, and especially in Zoar, Massachusetts, in mica schist, along the line of strike continued from Readsboro.

There are three beds of steatite in Marlboro. The most southern on the top of a hill in the west part of the town, north of the Methodist Church, and is the property of Hosea Ballou. The talcose schist has a strike of N. 20° E., and dips about 50° easterly. It is represented in Fig. 279. A, A, in the figure represents that part of the bed which is entirely serpentine; the steatite is at B and C; and at D is an opening made by quarrymen at its southern end. At this end the bed is fifty feet wide. The southern extremity of the steatite is concealed by alluvium. There are no indications of steatite or serpentine north of the representation. The total length of the bed was estimated at twenty-five rods. The steatite is of the first quality, being free from the brown spar which injures so much of the steatite in the slates. As the bed is upon the top of a hill, it is admirably situated for drainage.

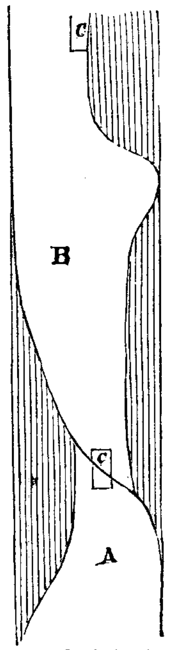
Fig. 279.



Ballou's steatite.

Half a mile north of this bed there is another upon the land of Ward Belus. In the bed of a brook there are two small beds of steatite, having the same inclination and direction with that of Ballou's. Each bed is about fifteen feet wide, and they converge towards each other, probably uniting upon the north side of the brook beneath the ground. The rock between the beds is tough hornblende schist. About four rods of the eastern bed are exposed to view, and about half as much of the western. The distance between these beds at their southern expanse is seventy feet; at their northern, forty feet. The steatite appearing to view was entirely filled with brown spar. Perhaps if the soil was removed from the concealed portions of the steatite, a better quality might be found. The soil might easily be removed by the stream. There is a good quality of actinolite at the northern part of the exposure. Another bed of steatite in Marlboro is on the line of strike of these two beds in the north part of the town, in talcose schist, upon the land of Clark Worden. It is represented in Fig. 280. The parallel lines upon the side of the bed represent strata of talcose schist, running N. 10° E., and dipping 50° E. At A the steatite is green and rather hard, being a rock intermediate between steatite and chlorite schist. B is entirely composed of the best quality of steatite, free from brown spar. At C, C, the steatite has been quarried. The bed is situated upon the top of a gentle hill, and both extremities are concealed by alluvium. The length of the exposure is twenty rods, and its width is four rods. At the south end of B there is a considerable amount of brown spar. The north end of B is the purest and whitest. The eastern projection of B into the adjoining schist is composed of an inferior quality of steatite, the poorest of any part of the bed.

Fig. 280.



Worden's Bed.

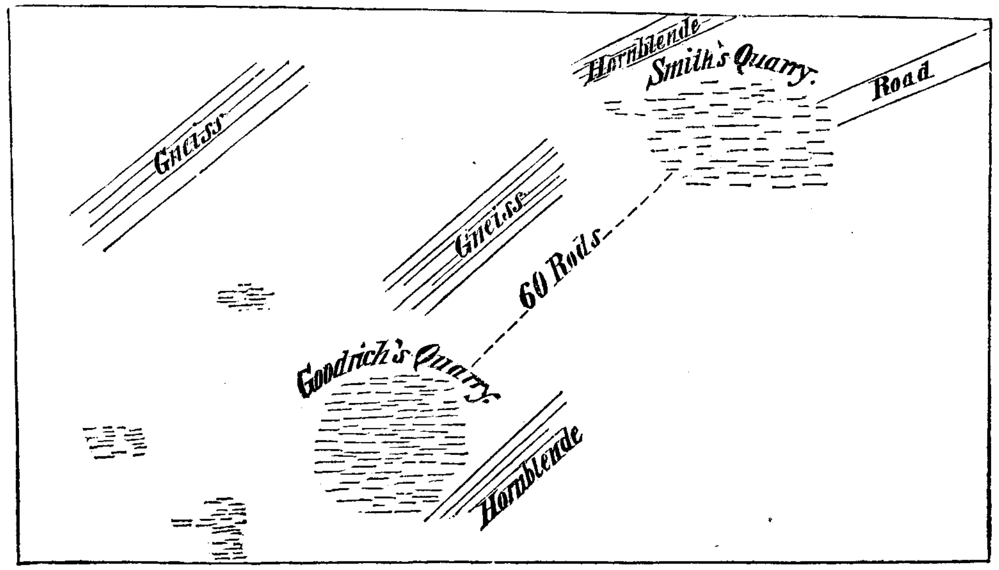
Passing over an immense bed of serpentine, we are brought, in the west part of Newfane, to a bed of both steatite and serpentine, which is worked by the Vermont Marble and Soapstone Company. The bed is situated upon a hill in the northwest part of the town, 1398 feet above the Connecticut River at

Brattleboro. The top of the hill is entirely composed of the magnesian rocks. The length of the bed is half a mile. The including rock is talco-micaceous schist, and is quite irregular in its position, but averages N. 15° E., in direction, and dip 75° E., though varying to perpendicular. The rock is less micaceous upon the east than upon the west side of the bed.

The width of the bed at its north part is not less than twelve rods. It is narrower at the south end.—The steatite and serpentine are strangely mixed together. Sometimes the serpentine entirely cuts off the steatite, and again the steatite nearly cuts off the serpentine. At the north end of the bed, the serpentine occupies the greater part of the bed, being inclosed on both sides by steatite. The general course of the bed is like an irregular vein of granite in limestone. We regret that, by an oversight, the figure drawn of this bed by the Principal of the Survey, for the Vermont Marble and Soapstone Company, several years since, was not copied into this Report. The quality of the steatite was described as unusually good. It is unusually free from foreign minerals, such as brown spar. There is also present an unusual quantity of the deep-green variety of steatite, which by many is regarded as the most valuable and beautiful of all. It appears here in the form of veins, from a few inches up to more than two feet wide. In one spot there is an apparent vein some eight or ten inches thick, of most excellent quality, running through serpentine. The minerals at this locality, are green talc, hornblende, actinolite, Adamsite, chlorite, garnet, and chromic iron.

We were informed of the existence of a bed of steatite in the southwest part of Townshend, but have not visited it. We examined a tubercular mass of steatite of small size, in the east part of Townshend, upon the land of David Bemis. Several excellent blocks have been quarried from this bed. It has been excavated to a depth of fifteen feet. The widest part of the bed is thirty feet. There seemed to be no irregularities in the form of this bed, and we saw no rock present except steatite. It occurs in gneiss, running N. 40° E., and dips 50° N.W. It is probably the same bed as that in Grafton, either upon the opposite side of an axis, or the same stratum prolonged into Townshend through Athens. We think it an interesting fact that upon the line of strike connecting the steatite beds in Grafton and Townshend, there occurs in Athens a bed of dolomite, having associated with it, hornblende, epidote and chlorite, minerals which more commonly are associated with steatite. It would seem as if for some reason this bed of dolomite was not converted into steatite, like its neighbors and congeneric beds in Grafton and Townshend.

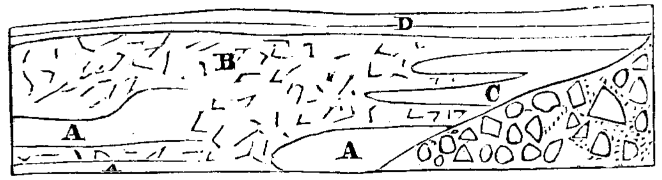
Fig. 281.



Steatite in Grafton and Athens.

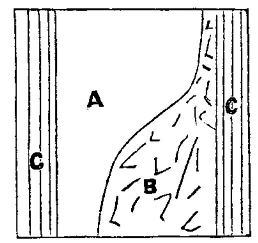
The two beds of steatite, one in Grafton and the other in Athens, only sixty rods apart, have been known for a long time, having been one of the first steatite quarries opened in the State. Their relative position is given in Fig. 281. Goodrich's quarry is situated in Athens, and Smith's quarry, the most northern, is situated in Grafton. The latter is northeast (N. 50° E.) from the former. Very much might be said respecting the position of the different kinds of rock in these quarries, but we must limit ourselves to the description of a small portion of them in detail. At the east end of Goodrich's quarry we find the following layers exposed to view in the excavation: On top is gneiss dipping 26° northerly, thickness not given. Next is a bed of disintegrated talcose schist, one and a half feet thick. Next is a bed of very much contorted talcose masses, four feet thick. Next is a bed of steatite, three feet thick, followed by four feet thickness of a very tough hornblende rock, ringing like iron when struck with a hammer. Below this is a bed of steatite, four feet thick. At this point the bottom of the quarry is reached. Adjoining this vertical section, upon the east wall of the quarry, the position of the different rocks is given in Fig. 282. The steatite occurs in lenticular masses, as A, A, A, and C. B represents hornblende rock and talcose aggregates, which occupy the greater part of the section. D represents gneiss overlying the magnesian rocks. At the right hand of the figure a large amount of debris is represented. Thus the steatite and associated rocks at this quarry are seen to be interstratified with one another, and forming irregular beds, the persistence of which cannot be depended upon. Generally in other localities the steatite or the hornblendic rock occur in one or more large beds by themselves. The steatite is all of excellent quality, and is highly prized by workers in soapstone. Upon an old opening, some twelve rods distant from Goodrich's quarry, to the southwest, we saw a good illustration of the manner in which a bed of steatite or associated rock may thin out, giving place to some other rock. It is represented in Fig. 283. A is a bed of steatite, ten feet wide, inclosed in gneiss, C, C. Associated with the steatite is a narrow bed of hornblende rock, B, not more than a foot wide at the surface. As the bed is quarried, the bed B rapidly increases in size, and at a depth of fifteen feet has occupied most of the space at first monopolized by the steatite. If the examination could be carried deeper into the earth, the steatite might be replaced entirely by the hornblende rock, or the steatite may expand again at the expense of the hornblende rock. We present this case as nothing peculiar to Goodrich's quarry, but as a sample of what may occur in every bed of steatite or serpentine. What we have called hornblende rock here is really a homogeneous compound intermediate between serpentine and hornblende rock. As the lenticular masses of steatite and serpentine are so common, it is no wonder that it is a question with many how these beds were originally derived: whether from aqueous or igneous, or aqueo-igneous forces,—or could they have been pockets in the rock which were filled up by chemical deposition?

Fig. 282.



Section in Goodrich's Quarry.

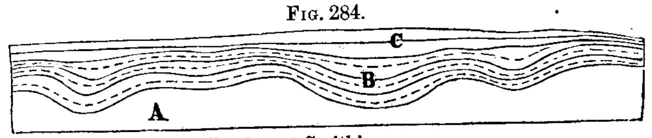
Fig. 283.



Steatite in Athens.

Smith's quarry is in general similar to Goodrich's; but the steatite is more uniformly in one mass. Fig. 284 represents a section at the north side of Smith's quarry. A, is steatite fifteen feet thick; B, represents masses of hornblende and talc ten feet thick; and C represents the overlying gneiss. This quarry will be exhausted sooner than the other. Owing to the peculiar nature of these masses of steatite we have found it impossible to sketch these beds of steatite in outline, like those in Marlboro. There is a curious tendency, in these as in other beds, of the strata to increase their inclination beneath the surface. For example, in Smith's quarry we noticed strata, at the surface dipping twenty degrees, but presently standing at an angle of eighty-five degrees.

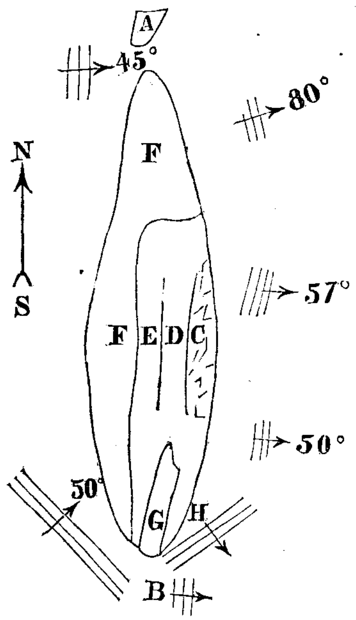
Fig. 284.



Section at Smith's quarry.

In Windham there are three beds of steatite. One of the largest is in gneiss in the southeast corner of the town upon the farm of Simeon Pierce. It is upon a hill half a mile south of Pierce's house. The bed is a mixture of good and indifferent steatite, with some serpentine. In much of the steatite a large amount of brown spar is present. The bed is fifteen rods long and four rods wide. The lines and arrows surrounding the bed are intended to show the direction and inclination of the surrounding strata of gneiss. This bed occupies the crest of the hill because it has resisted decomposition better than the adjacent rocks. Hence about fifteen feet of thickness of the stone are seen, which are generally hidden from view. The actinolite found at B, is the finest we have seen in Vermont. It can easily be dug with a strong spade. Seventy-five rods west of Pierce's steatite, separated by hornblende schist is a large bed of serpentine. Associated with serpentine there is another bed of steatite, in talcose schist, between Pierce's bed and Windham village.

Fig. 285.



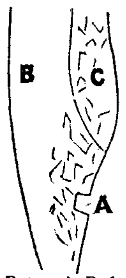
Pierce's Bed.

Explanation of Fig. 285.

A Vein of Quartz.
B Crystals of Actinolite.
C Serpentine.
D Steatite without admixture of Brown Spar.
E Steatite.
F Steatite filled with crystals of Brown Spar. Passes into some Serpentine.
G Steatite of excellent quality, four feet wide.
H Hornblende gneiss.

About two miles north of the village of Windham there is a bed of steatite and serpentine in talcose schist, upon the land of Abel Putnam. The bed is twelve rods in width, and of indefinite length. Where we examined it we found both steatite and serpentine present. The east part of it, at B, in Fig. 286, is mostly steatite of good quality. The west part of it, at C, is serpentine, which extends for some distance along this side of the bed. At A there is steatite and serpentine, the former of which has been quarried. The serpentine is very hard.

Fig. 286.



Putnam's Bed.

One-half of a mile east of this bed there is another bed of steatite upon the same farm, which was said to be superior to this one. We had no opportunity to examine it and judge for ourselves. The rock in the vicinity of these beds runs N. 10° E., and dips 60° E.

There is a large bed of steatite and serpentine upon the farm of David Jefts in Andover. It is in talcose schist, and is probably upon the line of strike connecting the beds in Windham and Proctorsville. There is said to be steatite in Chester. If so it is probably in the extreme west part of the town, and in the talcose schist.

In Ludlow there are five or six beds of steatite. Most of them belong to the Windham and Proctorsville range. In the southeast part of the town, upon the land of Benjamin Warren, there is a large bed, some parts of which are of good quality. Other beds occur in the east part of the town north of Warren's bed, upon the land of T. Fletcher and S. Ross. The strata is found in these localities upon the west side of serpentine. These beds all run N. 10° E. There is a bed of steatite of rather inferior quality in the west part of Ludlow, near the house of Levi Lawrence (one fourth of a mile southwest of it.) It overlies a bed of dolomite, and it is on account of this connection, perhaps, that it contains carbonate of lime. Its strike is N. 20° E., and its inclination 65° E.

There is a specimen of steatite in the Cabinet, from the land of Z. Parker in Ludlow. In the northeast part of Ludlow, upon the farm of Silas Works, there is still another bed of steatite in talcose schist. It dips west from 60° to 70°, and runs nearly north and south. It is apparently two rods wide. The stone is said to be rather coarse and to contain much brown spar.

In Cavendish there are certainly four beds of steatite, and there may be many others in the southwest part of the town, which have never been explored. Three of these beds belong to Isaac A. Brown, Esq., of

Proctorsville, and the fourth to Rev. Joseph Freeman of Proctorsville. The latter bed is situated a short distance behind Mr. Freeman's house, in Proctorsville. Its strike is N. 30° E. and it dips 70°. The bed is four or five rods wide, and is quite irregular in its shape. It appears upon the steep south side of a high hill; and as the strata are so nearly perpendicular a large part of the bed is exposed to view. The upper part of portions of the steatite passes insensibly into serpentine. There is much brown spar in a large part of this steatite, which injures the stone on account of its decomposition. Peroxyd of iron is developed by this decomposition, which gives a reddish hue to the stone where it has been weathered. The east bed of steatite belonging to Mr. Brown lies on the west side of the immense bed of serpentine. It was traced for a quarter of a mile in a ravine. Sometimes it was seen to be eight or ten rods in thickness. Some of the stone is quite hard, and seems to be intermediate in character between steatite and serpentine. This bed runs a few degrees east of north, and the inclosing talco-micaceous schist is nearly perpendicular. Brown's middle bed was said to be as good as the others, but was not visited. The west bed of Brown's lies on a precipice on the west side of a ledge of serpentine, and is more or less mixed with serpentine. It is four or five rods in width in many places. Some of it is green or chloritic, and is filled with large crystals of magnetic iron ore.

There is an excellent bed of steatite in gneiss in Baltimore, which is worked by the Vermont Marble and Soapstone Company. The strike of the inclosing gneiss varies from north and south to N. 30° W. There is much alluvium adjacent, so that the whole bed was not exposed at the time of examination, but so far as uncovered the steatite was about seventy-five feet long and forty-two feet wide.

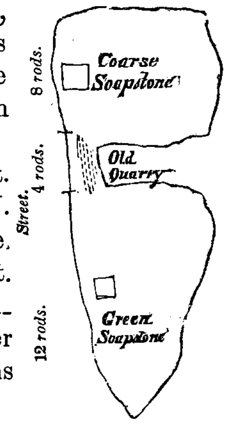
There is a small bed of steatite of inferior quality in gneiss, in the east part of Reading.

In Plymouth there are two beds of steatite. One is in the southeast part of the town half a mile west of the meeting house, upon the society lot, just upon the edge of some woods. Its walls are talcose schist running nearly north and south and dipping west from sixty to seventy degrees. The rock is rather coarse, and contains brown spar in small crystals.

Upon Plate XVIII. is represented a large bed of steatite and serpentine combined, which divides at its southern end into two prongs. Mr. Hager will give the details of the distribution of the two rocks upon this general deposit in his Report. We know, however, of four localities where steatite is found, all having the strike of N. 20° E., and an easterly inclination of near fifty degrees. A limited amount of very pure steatite is found on Mr. Pelton's land. On A. Bates' land, sixty rods distant, there is another outcrop of the same bed. On Bates' land, forty-five rods west, there is another bed of impure steatite, twenty-five feet wide. On J. Marsh's land there is another bed, of excellent quality, which is well situated for economical purposes.

There are two beds of steatite in Bridgewater. They are about two miles apart, and are upon the west bank of the north branch of the Otta Queechee River. The southern bed is of little consequence. The other contains valuable steatite, and is upon the farm of George Bugbee, one mile north of the center of the town. The steatite is fifteen rods wide, and passes under the hill northwest of it. The inclosing rock, on the south side, is talcose schist, but upon the northwest side it is tough hornblende rock, which rings like iron when struck by a hammer. Most of the stone is entirely free from any foreign mineral.

Fig. 287.



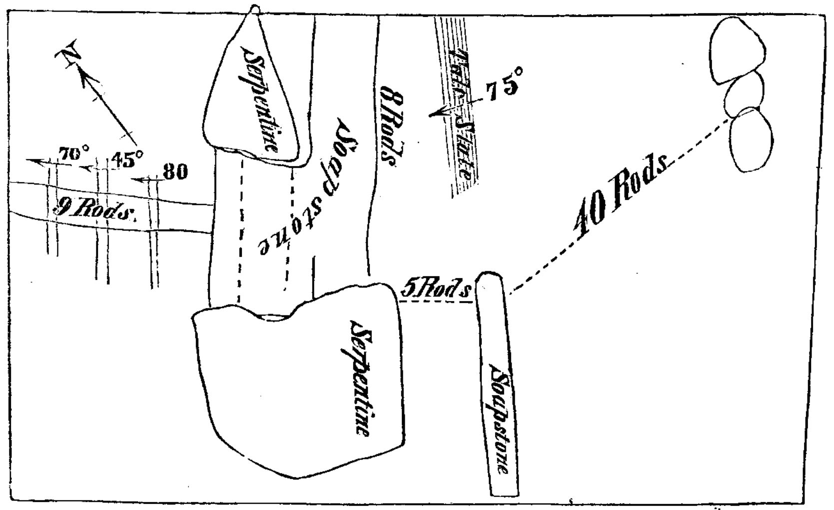
Steatite, Bethel village.

There are two beds of steatite in Thetford upon the east range of talcose schist. One of them is upon Jeduthan Taylor's land, running east and west, and dipping 42° N. The stone is impure. Fifty rods west of this, there is another mass of impure steatite. Prof. Adams has the following, respecting one of these beds in his Second Annual Report. Near the middle of the east side of this town, in micaceous hornblende slate, is an irregular bed of soapstone, about eight feet thick, which has been quarried. In the lower part of the bed it passes into a dark-green laminated talc, and in the upper part contains bitter spar and light-blue actinolite.

There are two beds of steatite in Bethel. One of them is in the village, upon the east side of White River, and is represented in Fig. 287. Its length is twenty-four rods. The north part is coarse steatite, and there is a green steatite in the south part of the bed. The old quarry in the middle is fifteen feet deep. The bed is upon the land of Peleg Marsh, and is immediately contiguous to the Vermont Central Railroad.

In the westerly part of the town there is another bed of steatite. In the north part of Bethel there is a bed of laminated talc, most of which is sufficiently compact to be quarried as steatite.

FIG. 288.



Williams' Steatite Bed, Rochester.

In the east part of Rochester, near the Bethel line, there are three different beds of steatite within the space of one mile. The principal ones are represented by Mr. Hager in Fig. 288. We add a description of these beds from the notes of the Principal of the Survey:

"Visited the serpentine bed and soapstone quarry two miles east of Rochester Center. The former forms an embossed hill, one hundred rods north of the soapstone. A great irregular mass of chlorite occurs at the top, full of crystals of magnetic iron ore. Asbestus (?) also occurs here in an adit about fifty feet long that has been driven into the hill. Also a fine white mineral (agalmatolite ?), seeming to form a coating on the serpentine.

"The soapstone forms several beds in a talco-micaceous rock, dipping at a high angle to the west. For several feet at the top the rock it abounds in veins of brown spar and fissures. But beneath this a very beautiful soapstone is found, entirely free from foreign minerals. The quantity of soapstone here is very great, and I should think the prospects very good; but the road is steep (most of the way descending) to the depot at Bethel, nine or ten miles.

"In the village of Bethel an enormous mass of greenish talc is found, coarse-grained and laminated, which has been wrought for soapstone, and though rather hard, I cannot see why it will not make good stone; though unlike any other I have seen. The rock appears to be stratified. Some of the rock at Rochester is of a light-green color and pure."

The serpentine represented in Fig. 288 is different from that described in these notes as being removed 100 rods from the steatite. The three beds of steatite are here represented, the most remote being forty-five rods apart. The largest bed in Rochester is reported to be nearly forty feet wide. The lines on the left hand side of Fig. 288 represent the position of the adit.

In Thompson's Gazetteer of Vermont it is stated that "steatite or soapstone is found in considerable quantities in the north part of Stockbridge, but it is of a quality inferior to that found in Bethel, Bridgewater and several other places in the State."

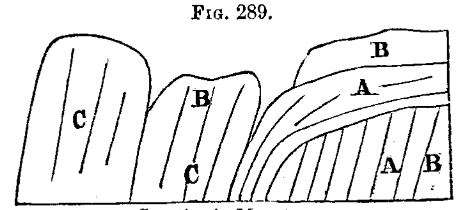
Prof. Adams reports the existence of a bed of steatite in Braintree in talcose schist, in a line with the steatite of Bethel and the Verd-antique serpentine of Roxbury and Northfield.

There are three beds of steatite in Warren. One is near the principal village, and another four feet wide near the River village in the south part of the town. Both of these beds are comparatively insignificant.

There is another of better properties and quality upon Hon. F. A. Wright's land, two or three miles northeast of the principal village, but we have not examined it.

One mile southeast of the village of Waitsfield there is a bed of steatite in talcose schist, upon Mrs. Jocelyn's land. The schists have the strike of N. 30° E., and dip 80° E. At the junction of the schists and steatite the strata are much contorted. On the east side, the steatite is tinged with decomposing pyrites. The bed is ninety feet long and eight wide, running to a point at each end. It is divided in the middle by a strip of impure serpentine into two layers of steatite, the most easterly of which is from three to six feet wide, and the other is from two to three feet wide.

FIG. 289.



Steatite in Moretown.

There are two beds of steatite in the northwest corner of Moretown. One of them is near the Winooski River, and the other is upon a hill a hundred rods or so south of it. The former is a very small bed, but the steatite is of good quality. The one upon the hill belongs to Deavitt and Stowell. Fig. 289 represents a section of this bed. A, A, represents the steatite; B, B, B, represents masses of chlorite; and C, C, represents masses of serpentine. The steatite varies from six to fourteen feet in width. It lies between nearly perpendicular beds of talcose schist, while its layers vary considerably. B, the cap rock of chlorite, seems to be nearly horizontal, and its associated steatite rapidly changes to nearly perpendicular. The serpentine is softer than usual. The steatite is mostly of slaty talc. It is entirely free from foreign minerals. It is unusuaally slaty, and hence would not be so valuable as masses from other quarries for large slabs. The bottom of the quarry is 270 feet above Winooski River.

There is a bed of steatite in the southeast corner of Duxbury, near the common corners of the four towns of Duxbury, Moretown, Waitsfield and Fayston.

There are three beds of steatite in Waterbury. Near Waterbury street there is one twelve feet wide belonging to H. H. Pinneo. It is not very long. Its existence was unknown till recently, when the loose soil concealing it was removed by a freshet. There is another bed nearly two miles north of Pinneo's, upon the same stream, belonging to W. Eddy. It is from twelve to fifteen feet wide. At Barrett and Gilman's ledge north of Waterbury Center, the rock runs N. 10° W., and dips 60°–70° E. The bed is from ten to fifteen feet wide. There is still another bed of steatite in the north part of the town, upon D. Gray's land. Mr. Hager has noticed a bed either of steatite or serpentine, upon the line between Waterbury and Bolton, upon the top of a mountain, near I. D. Clark's house.

There are two beds of steatite in Stow. One of them is mostly a compact kind of talcose schist, and the other is not much better, judging from specimens of the rock. The former is near Waterbury line, and the locality of the latter is three-fourths of a mile south of the village of Stow.

Messrs. Hall and Thompson regard a bed of steatite which they examined in Stow, as one of the best seen by them, in 1845. "It is extensive: the rock is compact, and is near good water power. It is accompanied by serpentine, and contains fine specimens of talc and actinolite."

In Cambridge on Sterling Mountain, near its top upon the east side, there is a bed of steatite which has been examined by Prof. Adams' assistants, but no record was preserved of their observations upon it. It is located in the old town of Sterling. We were informed in Johnson that much steatite of excellent quality occurs near the center of the old town of Sterling.

There are two beds of steatite in the northeast part of Johnson, which are said to be of inferior quality. There is a bed of excellent steatite in Eden. It is on Mr. Phillip's land, one mile west of the church. It is fifteen feet wide, and runs N. 16° E. There is another on Lowell Mountain. In the west part of Waterville there is a bed of steatite associated with serpentine. The stone is of most excellent quality, being remarkably free from brown spar. We have considered it the finest in the State.

There is a bed of steatite in Belvidere, three miles northeast of the meeting-house. The bed is about six rods wide where it has been quarried. The central part of the bed is rather a coarse serpentine. The talcose schist east of the steatite dips about 75° W. The steatite is unusually pure talc, so that it is very soft. Talc and actinolite are abundant at this bed also. There is a bed of steatite in the east part of Enosburgh.

There are said to be beds of steatite or serpentine in Berkshire; one near the west line in the south part of the town, and the other rather east of the middle of the town. There is a bed of steatite, serpentine and actinolite at Wright's Mills in Richford.

The several beds of steatite in Westfield, Lowell, Troy and Jay, upon the east side of the Green Mountains, are connected with two great ranges of serpentine. Beds of steatite are probably connected with these ranges more or less throughout their whole extent, though they have been described only at certain localities. We regret much not to have made a thorough stratigraphical examination of these magnesian minerals and associated hornblende and talcose schists. About a mile east of the village of Lowell, on the land of Mr. Pearl C. Bingham, is a bed of steatite. Part of the rock is filled with crystals of brown spar. Much of this bed is concealed from view. This is east of the east range of serpentine. West of the west range of serpentine there is another bed of steatite—a dark colored and hard rock. There are one or two other beds in Lowell, whose localities are unknown to us.

Half a mile west of the Troy line, and two and a half miles north of the south line of Westfield, there is a bed of steatite west of the west range of serpentine. There are many varieties of it, many of which are of excellent quality. Some of this steatite is of a very beautiful green color; some portions are cream-colored, mottled with darker colors; and some are of a light grayish-blue, very soft and free.

In South Troy there is a steatite in two places upon the eastern range of serpentine, in connection with chromic iron and magnetic iron. The same bed, continued in North Troy, is sixty or seventy feet wide. It abounds in light horn-colored and grayish-blue varieties of steatite, of good quality. We suppose that the normal position of steatite and serpentine here is that of a basin, and both above and below the serpentine beds of steatite may be found. Half a mile west of North Troy hotel we examined a bed of steatite, from one to eight feet wide. We saw it occasionally over a distance north and south of one-fourth of a mile.

In Jay there is steatite in two or three places. There are beds upon the west side of the serpentine containing the chromic iron, and also a mile and a half southwest from the iron ore. The strata here are vertical, running north and south.

BEDS OF SERPENTINE.

Although the number of beds of steatite in Vermont is more than double those of serpentine, yet there is much more of serpentine in the State than of steatite, because the serpentine frequently occurs in mountain masses. But it is more apt to be of an inferior quality than the steatite. There are scarcely any examples of serpentine in any rock except the talcose schist. The nearest approach to serpentine in the gneiss is in the tough hornblendic masses of Grafton and Athens, and in the southeast part of Windham. We have seen no serpentine south of that represented in Fig. 279, in the description of Ballou's bed of steatite, in Marlboro. From near Worden's bed, in Marlboro, which is near the north line of the town, for a distance of three miles along the line of Dover and Newfane, we suspect that there is a nearly continuous bed of serpentine. At all events, where Rock River cuts through the serpentine in Dover and Newfane (see Fig. 95), the serpentine is nearly a mile wide. It is of unusually poor quality along the gorge, as it is entirely colored brown by the decomposing constituent minerals, and is yet quite tough. It is undoubtedly from the decomposition of the serpentine that the cement of the alluvial conglomerate has been derived.

The steatite and serpentine, already described in Newfane, is the continuation of this bed. Serpentine seems to form the larger part of it. But after leaving the quarry of the Vermont Marble and Soapstone Company, we lose sight of the serpentine in this range until we arrive at Windham. In the southeast part of the town, on the border between the talcose schist and gneiss, is a large deposit of serpentine, on Asa Whiteman's land. It is seventy-five rods west of Pierce's steatite, the interspace being entirely hornblende schist. The bed is forty rods wide. It runs north and south, dipping 60° E. On the west side of the bed the rock is garnetiferous mica schist, having the same position as the hornblende schist upon the east side. Parts of it are of good quality. Foreign minerals are not abundant in it.

Northwest of this bed about a mile and a half there is a bed of serpentine and steatite. East of the village of Windham the same bed shows itself again in an enormous mass. Upon the same strike nearly two miles northeast of the village, a still larger hill of serpentine appears, belonging to John Greely & Co. The rock of the ledge is generally very hard. It was so immense that we did not attempt to estimate its dimensions. It is on the top of a high hill, overlooking the surrounding country for many miles. Its strike is N. 10° E., and its dip 60° E. The serpentine upon Abel Putnam's bed in the north part of Windham is represented in Fig. 286.

We cannot state how extensive this range of serpentine is developed in Andover and the west and south-west parts of Chester. Hills of it have been observed in the northwest part of Chester, extending into Ludlow and Cavendish. The amount is as great as in Proctorsville. Mr. Hager regards this outcrop of serpentine as commencing in Chester and continuing to some distance north of Proctorsville, and the width of the mass is essentially the same throughout. There are at Proctorsville two great beds of the serpentine. The most eastern is the largest, commencing at Freeman's steatite bed. It is separated by a band of talcose schist from the smaller western bed. The eastern bed is half a mile wide and forms a mountain mass. The beautiful Verd-antique serpentine is found in the larger of these bands near Proctorsville. It has been quarried somewhat, but not very extensively. Most beautiful slabs have been obtained from it.

There is much serpentine in Plymouth, in the northern bed of magnesian rocks, which will be described elsewhere in the Report. At the River village in Warren there is a bed of serpentine some rods wide, and of indefinite length. It forms quite a large hill. At its base there is the remnant of an old kiln where formerly the serpentine was burnt for lime! The fire had the effect of permanently destroying the green color of the stone, changing it to white.

At Roxbury there are two beds of the famous "Verd-antique marble." The larger one is about half a mile south of the village, and has been worked by the American Verd-antique Marble Company. It is unnecessary here to enlarge upon the beauty and durability of the serpentine which is here obtained, but simply to describe its geological position. It stands nearly vertically between layers of talcose schist which run N. 22° E., and dip 80° W. The bed is about thirty-five feet wide, and lies at the bottom of a hill within a few rods of the Vermont Central Railroad. The rock is traversed by numerous white seams of carbonate of magnesia, and hence perhaps the name of Verd-antique serpentine may be a misnomer, as carbonate of lime or dolomite is essential to the composition of the Verd-antique variety. Either dolomite or calcite, however, is present, for we have collected numerous specimens of the former, some of which are in the State Cabinet. We will speak more particularly of the character of this rock presently. Other minerals present are white and green talc, chromic iron, nemalite, brucite (?), asbestus, actinolite, etc.

There is another bed of this variety of serpentine about two miles north. Prof. Adams also speaks of the same variety in the west part of Northfield.

There is a large bed of serpentine connected with an iron ore, about a hundred rods north of Williams' quarry in Rochester. Also at Williams' quarry, as illustrated in Fig. 288. In connection with the steatite of Waitsfield and Moretown serpentine also occurs. Its relation to the steatite in Moretown, are given in Fig. 289. In the northeast part of Waterbury, between the houses of J. Barnes and J. Prescott, there is a large mass of rather porphyritic serpentine. Bowlders from it are found abundantly as far south as Moretown, proceeding in a straight line from the bed. Rev. S. R. Hall has marked a bed of serpentine upon a manuscript map in the east part of Middlesex.

There are a few large beds of impure serpentine upon the eastern range of talcose schist in Norwich and Thetford.

Half a mile north of the Norwich depot on the railroad, there is a very compact serpentine rock, which partially decomposes on exposure. The decomposing mineral may be a sulphuret, but the rock requires further examination.

A second bed is in the north part of the town. It is about half a mile wide where it crosses the town line. Its eastern limit is just one mile from Connecticut River. It is probably of great length.

There is serpentine connected with the steatite at Waterville, situated in the midst of the steatite, as if it were resting upon a steatite basin. Jasper Curtis, of St. Albans, informs us that there is an immense mass of serpentine at Hazen's Notch. We have had no opportunity to visit the locality. Connected with the steatite in Montgomery and Richford, serpentine also occurs.

Prof. Adams has the following respecting the serpentine in Lowell, Westfield and Troy:

"*Lowell.* Two ranges of serpentine commence in this town, near the head waters of the Missisco, and extend nearly into Canada. For the richness and number of the varieties, it would not seem possible that they can be surpassed, while their extent, amounting to twenty or thirty square-miles, is beyond the possible demand of all future ages. They are exhibited in several precipitous ledges, which are easy of access and of being worked.

"In this town we examined three of the principal of these ledges; one a mile and a half east, and another one-third of a mile west of the village, and a third in the north part of the town, which may be called respectively the east, west and north ledges.

"The east ledge the west side of a hill east from the village, whence it appears as a mass of pale ash-colored rocks, for such is the color of weathered surfaces. The number of varieties of great beauty, which may be found here, is remarkable; more than a dozen may be found within a few rods, consisting of the intermixture in veins, irregular masses, and grains of various shades of light and blackish-green with each other, or with brown spar, and the surfaces of the joints are very frequently covered with a thin coat of delicate amianthus, so as to resemble velvet, and are spangled with the brilliant surfaces of the brown spar. Of the uniform varieties there will be no difficulty, probably, in obtaining blocks of sufficient size for the ordinary demands of internal architecture. This ledge has recently been made more conspicuous by being burnt over, and probably has not before been visited.

"The west ledge has been well known to mineralogists, although the change of the name of the town, from Kellyvale to the less poetic name of Lowell, may occasion some confusion in the 'localities' of mineralogical treatises—a consideration which possibly may not have had due weight in the legislative decision on this change of name. This ledge has a western mural face, of one hundred and fifty to two hundred feet high, the lower two-thirds being covered with a debris, consisting of large fragments, which themselves might furnish many blocks for the saw. The varieties are rather less numerous and elegant than those of the east ledge, but blocks of good size and much beauty may be obtained with great facility. This locality has been much visited for asbestus. The north ledge is not far from the Troy line, and has a western mural face within five rods of one of the best roads in the State. It furnishes varieties similar to those of the west ledge.

"*Westfield.* One-half mile west of the Troy line, and two and one-half miles north from the south line of the town, a road crosses a ledge of serpentine and soapstone. The weathering of the serpentine here has revealed a jointed structure, which much resembles stratification in some parts, but for the most part they variously intersect as usual. This serpentine appears to be less beautiful than that of Lowell, although further examination would doubtless detect elegant varieties.

"*Troy.* The ledges of serpentine in this town are numerous and extensive. A little north of the north village we found soapstone and serpentine in junction, and at the junction we found a rock composed of rounded fragments of serpentine, mixed with soapstone, which, although not of economical value, may be of scientific interest. Within the north village, towards the west side, is a ledge of dark green serpentine, variegated with light green, and with pilose amianthus on the jointed surfaces.

"Between the furnace and the great vein of magnetic iron ore, the serpentine again appears, constituting the west side of a lofty hill. Here enormous ledges are easily approached from a good road, which runs along their base, while the Missisco is but a few rods to the west. But the ledge in which is the vein of iron ore, is, not only on account of the ore, but on account of the varieties of serpentine, an object of much interest. Elegant varieties are numerous, among which are most conspicuous the very bright-green noble serpentine, which covers most of the numerous jointed faces with a coat of one-eighth to one-half of an inch thick, and the spotted varieties. Numerous seams may render it difficult to obtain large slabs, but smaller pieces suitable for a great variety of ornamental purposes may be obtained, of great beauty, in any quantity."

This western range also passes through the east part of Jay, but there is nothing of additional interest concerning it to be related except that it contains large veins of chromic iron. There is said also to be serpentine in Cambridge, accompanying the steatite on Sterling Mountain.

STRATIGRAPHICAL RELATIONS OF THE STEATITE AND SERPENTINE.

Regardin · the steatite and serpentine as rocks of the same age, the question arises, how many bands or ranges of these beds are there; and how many of them can be referred to the same geological horizon? At the outset of this inquiry these ranges naturally group themselves into four different deposits, which we must at present consider of different ages—unless the doctrine of metamorphism may allow us to suppose that these formations are only repetitions of one another in different mineralogical conditions. The four groups of strata, to which these beds may be assigned are: 1. The talcose schist along Connecticut River. 2. The gneiss of Windham and Windsor counties, between the two deposits of talcose schist. 3. The talcose schist of the middle part of the State, together with the west range of talcose schist, which may be a repetition of that upon the eastern side. 4. The gneiss of the Green Mountains.

1. The talcose schist along Connecticut River. The beds of steatite in Norwich, Thetford and Fairlee are supposed to belong to a single range. There may be a bed of steatite west of the principal range in Norwich. If so, it is probably the same with the eastern beds, but repeated by synclinal axis.

2. The gneiss of Windham and Windsor counties. There are two lines of beds of steatite along this formation. We refer them to one geological horizon, supposing them to be repeated by undulations in the strata. The eastern line includes the steatite in the east part of Townshend, in Athens, Grafton, Baltimore and Reading. Upon the west range may be grouped a bed in the west part of Townshend, Pierce's bed in Windham, and a problematical bed in the southwest part of Chester. By consulting Section IV, it will be seen that the different beds dip in the same direction, while there are two axes between them. We regard Bemis' bed, in Townshend, which dips west, the same as the Smith and Goodrich beds in Grafton and Athens, but lying on the opposite side of the anticlinal; and that Pierce's bed, in Windham, is the same bed brought up again on the opposite side of a synclinal axis.

3. The great central range of talcose schist. There must be at least two different horizons of these magnesian rocks in this range. But one range is developed, or has been discovered south of Windham. Here there are two and perhaps three ranges of the steatite, for the strata all dip in the same direction. The serpentine near the village of Windham, that belonging to Greely & Co., and Putnam's bed, which is represented in Fig. 286, belong to the western range. The eastern range comprises Asa Whiteman's serpentine (though there is some doubt whether this class does not belong to a third range), a bed of steatite and serpentine in the south part of the town, and Putnam's second bed in the north part of the town. The next evidence of two ranges is in Ludlow. Levi Lawrence's bed is on the west side of the talcose schist, while all the rest in Ludlow and in Cavendish are on the east side of the schists. The strata, however, slightly approach the structure of a sharp synclinal axis, which would reduce these two bands to the same horizon.

At Rochester and Bethel these beds are represented upon Section VII, which can clearly be assigned to two horizons. The beds in Braintree, Roxbury, Northfield and Middlesex, evidently form one range, but may be the same with the ranges in Warren, Waitsfield, Duxbury, Moretown and Waterbury, owing to repetition of strata. But this western range is evidently composed of two ranges in Warren, and in Waterbury, independently of the repetition from the eastern part of the formation. The two great ranges in Orleans county are probably the same bed upon the opposite sides of an axis — which is regarded as an anticlinal by Logan, but a synclinal by Prof. Adams and by Rev. S. R. Hall.

Upon the west side of the Green Mountains, all the beds may be referred to one band, except those in Berkshire. But they undoubtedly are the same, as the strata in Richford are repeated in Berkshire by a synclinal axis.

4. The gneiss of the Green Mountains. But three beds of these magnesian rocks are repeated in this formation; and the existence of all these is problematical. But just south of the bed in Readsboro are two beds in Rowe, Massachusetts, which belong to the same geological age. These were probably formed at different epochs. Besides the bed in Readsboro, Vermont, there is one in Bolton, and another, of serpentine, at Hazen's Notch, in Westfield.

It is not impossible but that there may be only one range of beds in the talcose schist formation, and that the number of ranges now found in it show how many times the strata have been folded. It is possible, also, that these beds may indicate the limits of folded axes, provided that in the first place we can find an undisturbed region where their true stratigraphical relations to each other can be determined. The Canada Survey find two belts of magnesian rocks in the Quebec group, which is the prolongation of the talcose schist group into Canada. They place an anticlinal in the Troy valley, another in the Richford valley, and make great use of those beds of steatite and serpentine in studying the stratigraphical order of the rocks. They suppose that the magnesian rocks of Troy and Richford are connected beneath Jay Peak, in a synclinal basin.

CHARACTER OF THE SERPENTINE OF ROXBURY AND PROCTORSVILLE.

Three distinguished chemists of our country have examined the serpentine rocks of Roxbury and Proctorsville, and we present the results of their examinations.

Dr. A. A. Hayes, of Boston, State Assayer of Massachusetts, communicated to the Boston Society of Natural History, on October 17, 1855, and March 19, 1856, several analyses of these rocks, and remarks upon them, which were republished in the American Journal of Science and Art, Second Series, Vol. XXI, page 382 et. seg. Previously to the analyses he had examined the durability of the Roxbury serpentine, and pronounced it nearly equal to granite for its power to resist decomposition. We quote his analyses of the white veins traversing the Roxbury serpentine, as well as the basis rock itself.

"I. Analysis [of specimen from Roxbury.] That part which is purely white in color, can be separated from the general mass, in the form of milk-white fragments, translucent, crystalline; the cleavage planes reflecting a high luster. In hardness exceeds any variety of calcspar; it scratches the harder dolomites. The powdered mineral loses some humidity at 212° F.; at 450° the whole loss is 0.08 per cent. 100 parts of the dried powder consist of

Carbonic acid,	48.80
Magnesia,	45.60
Talc and trace of silicic acid,	3.60
Silicate protoxyd iron,	1.96
	99.96

proving it to be an *anhydrous carbonate of magnesia*. In diluted acids it hardly effervesces until heat is applied, and then exhibits an astonishing power of resistance to solution at the temperature of ebullition. The powder exposed to heat requires long calcination at bright redness for the expulsion of its carbonic acid, rendering its estimation difficult. This character may have caused an error in previous analyses of serpentine, and led to the conclusion that a hydrate of magnesia forms a part of the composition of all such rocks.

"II. The following results embrace the averages on compact, nearly white portions [of the veins]:

Moisture,	0.08
Water from hydrated minerals,	0.98
Carbonic acid,	47.16
Magnesia,	44.24
Talc, laminæ and trace of silicic acid,	5.20
Silicate of alumina,	0.64
Protoxyd of iron from sil. iron with manganese,	1.53
	99.83

showing the influence of a small admixture of the included minerals.

"III. In the following results, the average of the whole rock as quarried [in Roxbury] is given — the dark greenish-black, light-green and white colors intermixed. 100 parts divide into

Moisture,	0.40
Carbonate of magnesia,	38.00
Included minerals,	61.60
	100.00

"61.60 of the various minerals forming the base of the compound rock, consisted of

Combined water,	6.44
Silicic acid,	36.92
Magnesia,	10.52
Protoxyd manganese and proto-peroxyd of iron,	4.80
Alumina,	2.06
Chrome iron,	0.63
	61.37

"The basis rock, thus proved to be the hydrated ingredient, is an indefinite mixture of so-called serpentine. It is however easily resolved into greenish-white talc, asbestus in various forms, rarely actinolite, ordinary slate as silicate of alumina and iron, constituting an aggregate. But the most remarkable fact is, the entire absence of compounds of lime.

"In view of this chemical composition and its physical characters, I propose that this rock, quarried for ornamental purposes, be hereafter called serpentine marble."

Dr. Charles T. Jackson, of Boston, instituted a comparison between the American and European Verd-antiques, and communicated the results to the Boston Society of Natural History, February 20, 1856. We quote from it the following:

"The results to which I have arrived possess some scientific as well as practical interest, for they show a curious replacement of carbonate of magnesia for carbonate of lime, the magnesite being most abundant in the Vermont marble [serpentine], while calcite is the predominant spar in the European variety.

"Serpentine consists essentially of hydrous silicate of magnesia and silicate of the protoxyd of iron, with occasionally a little oxyd of chromium — these oxyds giving the green color to the serpentine. The presence of water in composision in serpentine materially affects its hardness, the softer varieties containing the largest proportion of water. In some varieties I found as much as fifteen per cent., while the lowest was seven per cent. Both the verd-antique serpentine of Europe and of Roxbury, Vermont, contain between twelve and thirteen per cent. of water. That from Proctorsville, Vt., contains but seven per cent., and that of Roxbury thirteen, while that from Europe contains 12.5 per cent.

"Verd-antique marble may be defined to be serpentine mixed with, or containing numerous veins of magnesian carbonate of lime. The relative proportions of these ingredients may vary considerably on account of the isomorphic or rather plesimorphic characters of the two minerals. Carbonate of the protoxyd of iron, in like manner being plesimorphic with both carbonates of lime and of magnesia, replaces either of those minerals in all proportions, without changing the angles of the crystals more than one degree.

"It will be observed on examination of the analyses I have made, that in the Vermont serpentine the white spar veins are chiefly composed of magnesite, while there are also veins consisting of magnesian carbonate of lime, and of carbonate of iron. The relative proportions of these magnesian and ferreous carbonates, in the Vermont marble, are nearly the reverse of those in the European variety; thus beautifully illustrating the law of isomorphous substitution of mineral ingredients.

"I. Chemical analysis of the white veins of European Verd-antique. These veins, picked out with great care, to avoid any mixture of particles of serpentine, yielded per cent,

Carbonate of lime,	81.00
Carbonate of magnesia,	11.70
Carbonate of iron,	7.30
	100.00

"II. Chemical analysis of the white veins of Roxbury Vt., Verd-antique marble. These veins were quite common in the slab examined by me. They were picked out with care to avoid any admixture of serpentine. On analysis, they yielded,

Carbonate of magnesia,	80.00
Carbonate of lime,	15.00
Carbonate of iron,	3.50
Silica, and loss,	1.50
	100.00

"It will be observed that the carbonate of lime in the European marble is represented by carbonate of magnesia in the Vermont variety, and the carbonate of magnesia by the carbonate of lime — a reversal of these ingredients.

"III. Chemical analysis of the magnesite veins in Roxbury Vt., Verd-antique. These veins are probably like those analyzed by Dr. Hayes. They yielded per cent,

Magnesia,	38.88
Carbonic acid,	37.12
Protoxyd of iron,	9.00
Undecomposed serpentine,	15.00
	100.00

"The protoxyd of iron was originally in combination with carbonic acid in the stone, forming carbonate of iron, an isomorph with carbonate of magnesia.

"IV. Chemical analysis of the dolomite spar veins in Roxbury Vt., serpentine. A cleavage crystal, with angles of 106°, 15, was analyzed, and yielded,

Carbonic acid,	46.50
Lime,	30.52
Magnesia,	18.47
Protoxyd of iron,	4.25
Silica,	0.05
	99.79

"In this mineral the carbonic acid is combined with the lime, magnesia, and protoxyd of iron.

"V. Chemical analysis of the serpentine of the Verd-antique of Europe. It was picked out clean as possible, reduced to small grains, and washed with very dilute muriatic acid to cleanse it from adhering carbonate of lime. The attack was made by means of carbonate of soda, in the usual manner of rendering insoluble silicates soluble in acids. The results obtained were

Silica,	42.40
Magnesia,	31.20
Protoxyd of iron,	13.90
Water,	12.50
	100.00

"The Roxbury, Vt. serpentine, analyzed in the same manner, yielded

Silica,	42.60
Magnesia,	35.50
Protoxyd of iron and oxyd of chromium,	8.30
Carbonate of Lime,	0.60
Water,	13.00
	100.00

T. S. Hunt, Esq., of Montreal, analyzed the white veins from the serpentine of Roxbury, and "obtained from 100 parts, 2.76 of talc, and 1.82 of silica, besides 2.40 of peroxyd of iron, corresponding to 3.48 of carbonate of iron, the rest being carbonic acid and magnesia, with a little manganese." His account of these veins and the serpentine is as follows: "The greater portion of the iron exists here [in the veins] as carbonate, as is evident from the fact that it is dissolved by a boiling solution of nitrate of ammonia; but there is also present a portion of silicate of iron and magnesia, decomposable by acids. In my analysis the powdered magnesite was digested for a long time at a boiling heat, with hydrochlorite acid; the insoluble portion was then boiled with strong sulphuric acid, and from the residue the silica was removed by a solution of carbonate of soda, the talc remaining.

"The talc thus purified from magnesite and serpentine by successive treatments with hydrochloric and sulphuric acid and carbonate of soda, was gently ignited, and then decomposed by fusion with carbonate of soda; it gave:

Silica, ...	62.60
Magnesia, ...	31.30
Allumina and oxyd of iron, . .	4.06
Water and loss, ...	2.04
	100.00

In the analysis of Dr. Hayes just cited [I.], the 48.80 parts of carbonic acid are sufficient only for 44.36 parts of magnesia, leaving 1.24 of this base in the form of a silicate decomposable by sulphuric acid. In order to determine the composition of this silicate, a dark-green portion of the rock was pulverized, and boiled for a long time with dilute nitric acid, which dissolved a large amount of magnesia with disengagement of carbonic acid; the solution contained besides, magnesia, iron, manganese and a trace of nickel, but no lime. The undissolved residue was then boiled with a solution of carbonate of soda, which took up a considerable amount of silica derived from the silicate which had been partially decomposed by the nitric acid, and left a dense granular matter mingled with silvery scales of greenish talc, which were in great part removed by washing. The denser silicate was then dried at 250° F., and submitted to analysis. By ignition it lost 11.40 per cent, and then gave to a boiling solution of nitrate of ammonia a quantity of magnesia equal to 1.21 of carbonate. Another portion was decomposed by sulphuric acid, and the silica separated from the insoluble talc by a solution of carbonate of soda. The results of the analysis were as follows:

Silica, ...	39.60
Magnesia, ...	36.72
Protoxyd of iron, ...	4.86
Oxyd of nickel, ...	traces
Talc, ...	6.80
Water, ...	10.77
Carbonic acid, ...	0.63
	99.38

"Deducting the talc, the carbonic acid, and the amount of magnesia required to form with it 1.21 of carbonate, we have for the composition of this silica dried at 250° F:

Silica, ...	43.34
Magnesia, ...	39.55
Protoxyd of iron, ...	5.32
Oxyd of nickel, ...	traces
Water, ...	11.79
	100.00

"This is the composition of serpentine, and the ophiolite of Roxbury is thus shown to consist of serpentine and talc, intermixed with a ferriferous carbonate of magnesia; the compact asbestus of Dr. Hayes is nothing more than serpentine."

The result from a comparison of all these analyses is, that the rock at Roxbury is a serpentine of the usual character, penetrated by veins of ferriferous carbonate of magnesia and dolomite. We cannot agree with Hayes and Hunt that there is no dolomite present. Its peculiar crystalline forms are too well marked and too numerous in the bed, and numerous large rocks quarried from the bed, to admit of doubt. Yet there may be large slabs of the serpentine which contain no dolomite, and it was doubtless these that were examined by these two chemists; especially as those parts which contain the dolomite are less ornamental, and are not often transported from the quarry. The magnesite forms finer veins than the coarse bunches and veins of the dolomitic mineral. We have subjected to analysis specimens of the dolomitic mineral, and find it to be a true dolomite. We think it is as abundant as the purely magnesian mineral.

Dr. Hayes made an examination of the serpentine at Proctorsville, etc., which we will add in his own words: "This mineral [at Proctorsville] has been described as a serpentine, and its physical characters generally entitle it to be so considered. It is traversed by thin white veins, producing a variety in its otherwise deep-green color. The averages of a number of samples are included in the following determinations:

"IV. 100 parts of the Proctorsville serpentine afforded

Moisture, ...	.40
Carbonic acid, ...	17.05
Magnesia, ...	16.00
	33.45

As the cementing material, leaving 66.55 as basis rock, composed of

Combined water, ...	6.21
Silicic acid, ...	36.10
Magnesia, ...	18.70
Proto-perox. iron and manganese, . .	3.40
Alumina, ...	1.13
Chrome iron, ...	.92
	99.91

"V. 100 parts afforded

Water, ...	5.60
Carbonate of magnesia, . . .	28.40
Basis rock, ...	68.00
	100.00

"A number of similar determinations were made on the rock obviously composed of talc and compact asbestus, cemented by a small proportion of carbonate of magnesia, in an anhydrous state.

"The serpentine of Newfane also afforded carbonate of magnesia, in variable proportions.

"Several European specimens, from unknown localities, were found to consist of associated magnesian minerals, cemented by anhydrous carbonate of magnesia. As a general expression, asbestus is the most abundant simple mineral, and it presents itself under forms in which it is recognized with difficulty. Talc is also largely intermixed in the basis rock. The coloring material of serpentine is found in several minerals, and although here included as a silicate of the proto-peroxyd of iron, I have deemed it worthy of a particular examination, at a future time."

In respect to the last point, we would inquire whether the constituent water may not give the color. For if the green color was derived from a salt of iron, then when the rock was heated to a redness the green color would change to red, the color a higher oxyd of iron; just as the Vermont yellow ochres and clays, when heated, change to red ochre and bricks. But if the constituent water gave the green color, then would the serpentine become white when heated. This inquiry was suggested to us in Warren, where a large pile of white calcined serpentine was shown to us, which had formerly been burnt for lime by persons who were unacquainted with its composition. It had been exposed to the weather for many years, yet the red color of the peroxyd of iron was nowhere apparent.

The researches relating to the composition of these serpentines have an important bearing upon our theories respecting the origin of these rocks. Dr. Hayes' views go to show that the serpentine rocks are of aqueous or hot water origin, as a heat above that of 500° F. is inconsistent with their chemical composition.

Geological Position, Equivalency, Origin and Metamorphism of Steatite. *

Steatite is undoubtedly a variety of talc, both of whose normal composition is

Silica,	62.61
Magnesia,	32.51
Water,	4.88
	100.00

In Vermont, indeed, the purest varieties of steatite, or soapstone (which here is the more usual name), are talc, whose folia adhere together firmly enough to be formed into blocks. In common soapstone the folia seem to be crowded together, and frequently mixed with some other minerals.

Talc is a distinct hydrous silicate of magnesia. Chlorite contains only half as much silica, and takes alumina and iron into its composition as essential ingredients. Nevertheless we have not attempted to distinguish between the light colored steatites of Vermont, and those green and more compact varieties, which form the most valuable of soapstones, but which we have supposed to be chlorite; though in the absence of analysis it would not be strange if they should turn out to be green talc.

The steatite of Vermont generally forms limited beds in talcose schist. It occurs, also, in mica schist, as at Cavendish, in gneiss at Grafton, and near Perkinsville in Weathersfield.

Hornblende schist also sometimes forms at least one of the walls, and on the Hoosac range of mountains in Massachusetts, which is a continuation of the Green Mountains, this association is quite common. Masses of serpentine are also almost always found in connection with the steatite, the two rocks passing insensibly into each other.

*By E. Hitchcock, Senior.

It is probable that steatite and talc result, in all instances, from the alteration of other minerals, of which there are many containing silicate of magnesia; others, such as feldspar, hornblende, mica, garnet, augite, topaz, &c., contain silicates of lime, alkalies and alumina, which the sulphate of magnesia might decompose and convert into silicate of magnesia. Now that salt is present in some springs and rivers, Bischof calculates that the Rhine at Borm contains sulphate of magnesia enough to form, "in a year a bed of steatite 3460 feet long and one foot thick," and since sea water contains 110 times more of this salt than the Rhine, it might make the bed 110 feet thick in the same time larger than any known deposit of that substance.

The beautiful green variety of steatite, which we regard as chlorite, undoubtedly had an origin similar to talc and common steatite. This variety, however, sometimes occurs in the form of veins, or dikes, of which the best examples we have met are in the west part of Newfane and in Cavendish. These dikes, sometimes two or three feet thick, usually penetrate serpentine. Chlorite is undoubtedly the product of alteration, and its occurrence in drusy cavities and fissures, proves that it was formed in the wet way. Indeed we cannot conceive how any chemical geologist can bring himself to believe that the chlorite dikes in serpentine have been injected, like lava, in a molten condition.

We wish we were able to say something satisfactorily upon the extraordinary power possessed by steatite, to retain caloric when once heated. The whole mineral kingdom furnishes nothing to compare with it. But no careful experiments have been made that we have met with on this subject; nor have we found any leisure to institute a series of such experiments. We think that interesting results await him who shall do it. Nor can we doubt that this property will be yet turned to more account than it now is, in the arts and domestic economy. We think, for instance, that it can be used to advantage in providing the poor of our cities with warmth in the winter, and we suspect that some scientific truths yet undeveloped, respecting heat, might reward the careful experimenter. But we have not room to go into details.

Geological Position, Origin, and Metamorphism of Serpentine.

We place this rock in the stratified class, although we have rarely met with distinct stratification in it. It forms beds sometimes of great thickness in the foliated rocks, but does not cut across them, as does granite, syenite and trap, though small veins of it, especially of the noble serpentine, are sometimes found in limestone. In Vermont, serpentine is almost always associated with steatite and talc, in the talcose slate formation. It occurs, however, in mica schist, as at Cavendish; and in gneiss, as at Grafton. Sometimes it is divided by planes, which generally are parallel to the walls, but they rarely extend to any great distance, and are undoubtedly superinduced structures. Yet they may be parallel to the original planes of stratification, or they may be simply joints.

If in any other parts of the world serpentine was protruded as a melted mass into the stratified rocks, we have met with no such example in Vermont. There it is most obviously the product of metamorphism. It probably had the same origin as steatite. Like steatite it is in its purest state a hydrous silicate of magnesia, having four equivalents of silica, nine of magnesia, and six of water; or in one hundred parts, 44.02 of silica, 43.11

of magnesia, and 12.87 of water. Most serpentines contain alumina and iron in considerable quantity, and often some lime, potash and soda; but these seem not to be essential.

According to these views, serpentine may have been derived from the same minerals as steatite: such as hornblende, mica, feldspar, garnet, augite, &c. Indeed it seems probable that some beds of hornblende schist and diorite, or greenstone, have been changed into serpentine. Hornblende, but rarely greenstone, is often associated with it in the Green Mountains, and such a metamorphism is quite possible. Sir William Logan, however, is of opinion that the Green Mountain serpentines have resulted from changes in silicious dolomites and magnesites. But since it might be derived from so many sources, it is not probable that sometimes it may have resulted from the metamorphosis of one mineral and sometimes another? We think that by a careful examination of the numerous beds of serpentine in Vermont, the remnants of the different formations from which it was derived, such as dolomite, hornblende rock, talc, steatite, chlorite, &c., may be discovered. The connection between serpentine and steatite is seen almost everywhere, and the two rocks often pass insensibly into each other, so that specimens of almost every intermediate grade may be found. A good locality for seeing this is near the Rutland and Burlington Railroad, a little west of Proctorsville. Here enormous masses of serpentine are interposed between strata of mica schist and steatite. Between the latter rock and serpentine there is generally no well marked division, and if anywhere in the State we could find evidence that the two rocks had been forced together, it would be here. Yet neither of them appear to have been protruded into the strata of schist; but the most satisfactory explanation of the phenomena is, that both of them are products of metamorphism in the wet way, as already described. Why the whole mass was not pushed to the ultimate limit of metamorphism, which we suppose to be serpentine, rather than steatite, we confess ourselves unable to show; though we presume it depended upon the temperature, or the character and amount of ingredients held in solution by the water of metamorphism. We think that these points will ere long be settled by the researches of chemical geology. But it will require careful and laborious investigations.

If the views above expressed are correct, the age of the serpentine is probably the same as that of the steatite and the talcose schist. On this point we have already stated all that we know, which indeed is but very little.

As to the stratification of serpentine, our conviction is, that ninety-nine-hundredths of the rock in Vermont do not show it any more than granite. Indeed, we think that all the divisional planes in it are superinduced. Where it passes into talc, or steatite, it exhibits a somewhat foliated structure, whose strike and dip correspond to those of the adjoining schists, and may therefore correspond to the original stratification before the metamorphism of the rocks. We think, however, that it does not show any more distinct marks of stratification or of foliation than we have seen in syenite.

The distinction between stratified and unstratified rocks has been usually regarded as one of the most trenchant and reliable in the science of geology. And so long as it was considered a certain fact, that the stratified rocks were exclusively deposited by water, and the unstratified all melted by dry heat, it is not strange that geologists should have looked upon the line between the two classes as very distinct and recognizable. But now that it is so generally admitted that hot water has been the most efficient agent in

metamorphosing the stratified rocks, and converting some of them into the unstratified, we can see how the distinction between them should often be very obscure and uncertain. Such is certainly the case with serpentine and dolomite, both of which are sometimes stratified, and sometimes unstratified. We are apprehensive that some other system of classification must be adopted, to include such rocks, and also some varieties of gneiss, and even some of the schists.

SACCHAROID AZOIC LIMESTONE.

BY C. H. HITCHCOCK.

Beds of limestone and dolomite are found in the gneiss, talcose schist, and calciferous mica schist of Vermont. Those which occur in the latter formation have already been described, on account of their stratigraphical peculiarities. But those which are found in the gneiss and talcose schist deserve a separate description. They are azoic, as they occur in connection with unfossiliferous rocks. As they are generally white and highly crystalline, thus resembling loaf sugar, they are termed saccharoid. In some situations the rock is dark-colored, or it may receive various other colors from the minerals disseminated through it.

Saccharoid limestone occurs in Readsboro, Whitingham, Wilmington, Somerset, Statton, Jamaica, Townshend, Athens, Windham, Andover, Mount Tabor, Weathersfield, Cavendish, Ludlow, Plymouth, Mendon, Rochester, Bethel, Hancock, Granville, Moretown, Duxbury, Johnson, Waterville, Bakersfield, Richford and Lunenburgh.

In Whitingham the limestone is largely developed in the gneiss. There is a bed of very crystalline limestone upon J. Kentfield's land, in the western part of the town. Analysis shows it to be nearly pure carbonate of lime. It is composed of carbonate of lime, 97.5; carbonate of magnesia, 2.1; alumina and peroxyd of iron, 0.2; and of silica, 0.2. Its appearance is saccharoid, and the west part of the bed is a very clear white. The strike of this bed is N. 10° W., and the dip is 25° W. Jointed planes in the limestone run N. 80° W., and dip 80° S. The width of the bed is very great. We could not ascertain its exact limits because of the abundance of drift covering the rocks. Other bright colored limestones are found at the bed besides the white. Very near this bed we found other smaller beds, a few inches in thickness. We are inclined to believe that small beds of limestone are very numerous in Whitingham and Readsboro, for we saw several of them in passing from Kentfield's bed to Deerfield River. Some of them were several feet thick, and have been used for the manufacture of quicklime. Other beds of limestone are said to occur west of Deerfield River, in Readsboro.

There is a large bed of limestone in Whitingham, also, upon the land of Jonathan Dix and Shubal Atherton. It is about two miles west of the village of Whitingham, and occupies the bottom of the valley, even in the bed of a small stream. Its strike is N. 10° W., and its dip is 40° W. It is three or four rods wide. It is white and decidedly crystalline, though often containing bronze-colored mica, and sulphuret of molybdenum in small plates. Associated with it, also, are actinolite, augite, and mussite. It may be traced for a mile or two along this stream. It underlies Kentfield's bed, being separated from it by gneiss.

From several different persons we have heard of the existence of a bed of limestone in Wilmington, but we have not seen it. It is said to be upon Haystack Mountain, and to be upon an island in a pond. Others say that it is less than two miles west of the village.

There is an elegant variety of dolomite east of the iron mine in the southeast part of Somerset. Some of it closely resembles the purest loaf sugar. In Stratton (what was formerly a part of Somerset) there are two deposits of limestone, the most northern of which belongs to Rufus Lyman, Esq. There are two beds near each other upon Lyman's farm, the widest of which is four rods wide, and the other is only ten feet wide. Their strike is N. 30° E., and their inclination 45° E. Joints in them run N. 10° W., dipping

45° W. An analysis of this rock shows its composition to be, carbonate of lime 65.41, carbonate of magnesia 30.05, carbonate of the protoxyd of iron 1.61, insoluble matters 2.58.

There are two or three large beds of limestone or dolomite in the east part of Jamaica, which we have not explored. Their general position upon the State Map of Mr. Walling is indicated by the word "limekiln," in the northeast part of the town. Their line of strike will by no means coincide with that of the beds in Somerset and Stratton. One belongs to A. Twitchell, Esq., and another to W. Thayer, Esq. We understand that there is a third bed in the vicinity. They are in talcose schist. In the gneiss in the west part of Townshend we found several strata of dolomite. These may indicate the presence of a larger bed in the vicinity.

Near the south line of Athens there is a large bed of dolomite, which is quarried by William Holbrook, Esq. It is in gneiss, running N.E. and S.W., and dipping 48° N.W. There are about twenty-five feet thickness of dolomite which is distributed through three or four beds. This is one of the best beds we have seen in the State from which to obtain specimens of highly colored dolomites. The white saccharoid variety prevails; but red, yellow and green colors, of various shades, abound. Associated with the dolomite are various minerals which usually accompany steatite rather than dolomite, such as hornblende, chlorite, talc, epidote and tourmaline. This fact may throw light upon the origin of steatite. There is a bed of limestone in gneiss in Mount Tabor. Its locality is indicated by the word "limekiln," on the State Map.

In the south part of Windham there is a bed of limestone. In the town of Andover there is a limekiln upon the land of Mr. Hutchins, in the west part of the town; also another in the north part of the town. These kilns must, of course, be supplied with limestone from their immediate vicinity, and hence we conjecture the existence of two beds of limestone. East of Simonsville, also, there is a considerable amount of limestone. We were informed that there were very few farms in the territory of Andover upon which some "bunches" of limestone might not be found. In the south part of Ludlow there is a bed of limestone of considerable thickness near the house of A. Adams. It is traversed by veins of quartz. It is not pure white, but rather a gray color. An old limekiln is located by its side. In the west part of Ludlow there is a bed of dolomite, twenty feet wide, upon the land of Levi Lawrence, Esq. It is connected with steatite. The bed runs N. 20° E., and dips 65° E. These beds of limestone and dolomite in Windham, Andover and Ludlow, are in the talcose schist.

There are three beds of dolomite in the gneiss of Cavendish. One of them is half a mile east of the village, upon the south side of Black River. It belongs to Christopher Webber, Esq. Beautiful specimens of white and colored dolomites may be collected here. Much of it is of a dingy-white color, with thickly disseminated grains of translucent quartz, in consequence of which it is quite friable. It runs north and south and dips 30°W. It is about twenty-five feet thick, and can be traced three or four miles in the direction of the strike. It appears in the east part of the cut in the railroad at Cavendish, which is represented in Figs. 298 and 299. Its route lies along the course of the R. and B. R. R. in the old river bed between Cavendish and Gassett's Station. Probably the former course of the river was partly determined by the softer character of the rock; as we think is also a part of its present course north of the Falls. This dolomite is composed of carbonate of lime 53.8, carbonate of magnesia 43.3, and silica 2.9. At the Upper Falls on Black River, not far from the east line of Cavendish, there is another fine bed of white dolomite, parts of which contain crystals of tremolite in abundance. There is a still larger bed in the north part of the town, which lies partly in Cavendish and partly in Weathersfield.

In Weathersfield the dolomite is abundant. It is continuous in the vicinity of Black River from near Perkinsville to Downer's tavern, near the west line of the town. Its direction is about N. 10° W. There is a small undulation in the strata here, which is probably the cause of the continued appearance of the dolomite. We are inclined to think that the dolomitic beds at Amsden's mill, and Craigue's quarry upon a branch of Black River may be the same bed as that just described, but repeated by undulations in the strata. The one at Amsden's mill dips 60° W., the one at Craigue's quarry dips 16° E. They both are on the east side of the river, and not more than sixty rods apart from each other. As the strikes coincide, we suppose these beds to be upon the opposite sides of the same anticlinal axis. The strike at Amsden's bed is N. E. and S. W., and the dip is 52° S. W. The rock is mostly white. It contains many veins of micaceous iron ore. The limestone is of the same quality at Craigue's quarry. Connected with it there are two trap dikes made up of concretionary masses which cross the strata, and are so inclined as to form an anticlinal with each other. One dips southerly 59°, and the other northerly at about the same angle running N. 60° E. The removal of the limestone shows these dikes beautifully. There are several small beds of limestone north of Amsden's mill in the region called Greenbush. One bed is on the west side of Little Ascutney. Probably the valley west of this mountain originated in the easily decomposing character of the rock.

The largest deposit of dolomite in the azoic rocks is in Plymouth. For a proper idea of its distribution we refer to Plate XVIII. It probably commences in Ludlow, and extends into Sherburne, along the great valley of Black River, and Otta Quechee River. It is said to extend into Bridgewater. We suspect that it may connect with the large bed of limestone in Mendon, and there is a possibility that this limestone is a repetition of the Eolian limestone upon the west side of the Green Mountain anticlinal. Specimens of this limestone which have been analyzed prove it to be a dolomite. Some beds of it make an excellent marble, as the brecciated marble east of Plymouth Pond belonging to the Neshobe Company, will show. It is brecciated a little like the Winooski marble. Measured in several places in the north and middle parts of the town the strike of this limestone is N. 10° W., and the dip 45° E. The invariable dip is to the east. One of the most interesting stratigraphical features of this limestone is its interstratification with quartz rock and talcose schist in the south part of the town. Not less interesting is its development upon the east side of a great range of mountains (Mt. Tom), running southerly almost parallel to the principal belt. Micaceous oxyd of iron is common in the dolomite in veins. Probably from this ore, and the iron in the composition of the dolomite, the tertiary hematites in the south part of the town were derived. The color of the Plymouth dolomite varies from white and reddish-white to a dark bluish or dun color. Other facts respecting this limestone will be given in the Geology of Plymouth.

In the northeast part of Mendon, upon the west side of the summit of the Green Mountains, there is an unknown area underlaid by white limestone. As bowlders of it are scattered over a large area, its extent is probably considerable. And we have found ledges of it at least a mile distant from each other.—One ledge of limestone shows a dip of 25° N., and a direction of east and west. Another set of strata run N. 10° E., and dip 25° E. This is the more usual position, we suppose. The ledge examined is ten rods wide, and no rocks crop out at the surface within two miles of it. The limestone is white and fetid. It reminds us more of the Eolian limestone than of the azoic. It is said to extend into Sherburne. It is probably a bed in gneiss.

Half a mile south of the village of Hancock there is a bed of limestone, of large extent. It is not a dolomite, though it contains a little magnesia. It is composed of carbonate of lime 90.3, carbonate of magnesia 6.9, oxyd of iron a trace, silica 2.8. The silica occurs in grains.

In the middle of Granville, along the west side of the valley, a bed of limestone extends for one or two miles. It is probably connected with a bed in the north part of the town on the land of William C. Chaffee, Esq. There are two varieties of the limestone here. One is white and granular; the other is dark-blue and compact. The former upon analysis is found to be composed, of carbonate of lime 89.741, carbonate of magnesia 4.264, oxyd of iron and alumina 2.420, silica 4.875. It occurs in two beds of unknown width. About ten feet in width of one of them was exposed to view. It dips 63° E. and runs N. 20° E.

There is a large bed of dolomite in Rochester, the details of which are not before us. In the west part of the town we found occasional layers of dolomite, as also in the north part of Bethel, but they could not be designated as large beds.

There are two quarries, called marble quarries, in the northwest part of Moretown, which belong to the same belt of rock. The most northern is ten or twelve feet wide. It is both white and clouded, and the strata are compact, somewhat in the manner of marble. West of it there is another bed still smaller. Its strike is N. 3° E. It stands upon its edges.

There is said to be a bed of limestone in Duxbury.

Two or three miles north of Johnson village, there is a bed of limestone upon the land of Robert Balch, Esq. The prevailing color is white; but varieties may be found of blue, pink, and light brown colors. The bed is fifteen feet wide, and is associated with a chloritic conglomerate or sandstone. The strata are somewhat contorted, but their general direction is N. 40° W., and their dip is 50° N. E. A small bed of galena occurs in this bed which is one inch wide and four feet long, so far as it has been explored. The rock is burnt for lime, and an excavation has been made in it fifteen feet wide and two rods long. The rock adjacent contains many seams of carbonate of lime. In the vicinity there is a cave one hundred feet long, which may once have been occupied by limestone. Prof. Thompson visited a bed of limestone in the northwest part of Johnson, and found it to be "white for the most part, but with seams and cavities containing the black oxyd of manganese, which in burning gives a dark color to the lime."

There is a bed of white granular limestone in Waterbury, showing itself in several places along the road from Johnson to Bakersfield. The limestone is generally friable, but is in some places nearly as compact as marble. It is only a few feet wide. All the beds we have described after the Plymouth deposit are in talcose schist.

In the northeast corner of Bakersfield there are beds of white limestone in talcose schist, upon the land of Mr. Hardy. These beds are from six to ten feet thick, with the direction of N. 5° E., and they dip 75° W. Veins of white quartz cut through the beds transversely. The limestone is composed of carbonate of lime 92.9, carbonate of magnesia 5.5, and of silica 1.6.

There is said to be a bed of white limestone in Richford. It must belong to the same range with the beds in Bakersfield and Waterville, all of which lie west of the Green Mountain anticlinal.

In the Report on the Geology of New Hampshire, Dr. Jackson has given an analysis of azoic limestone from Lunenburgh in Vermont. It is from Col. White's quarry. It must be from a bed in the eastern range of talcose schist.

In Columbia, N. H., only two miles east of the Vermont line, we visited a bed of limestone which may be of as much service to the citizens of Vermont as of New Hampshire, as it is in a region where limestone is very scarce. It is a blue, compact, indurated rock, forming a bed four feet thick in mica schist. It dips 25° E. It closely resembles the limestone of Bernardston in Massachusetts, except that it has been indurated. The mica schist adjacent still more closely resembles the mica schist of Bernardston.

Geological Position.

Like the beds of steatite and serpentine, the beds of saccharoid azoic limestone are of the same age as the gneiss and talcose schist which inclose them. The beds of limestone are more abundant in gneiss than were the beds of steatite. Like the magnesian beds, the calcareous beds can probably be assigned to two lines of different ages, and they are also found upon both sides of the Green Mountains in the north part of the State. By examining the course of these beds upon the map, a clearer idea will be obtained of their stratigraphical relations, than by a prolonged description.

The origin of azoic limestone must have been similar to that of the Eolian limestone, under which we have presented our views.

REPORT

ON THE

GEOLOGY OF VERMONT:

DESCRIPTIVE, THEORETICAL, ECONOMICAL,

AND

SCENOGRAPHICAL;

BY

EDWARD HITCHCOCK, LL.D.,
EDWARD HITCHCOCK, Jr., M.D.,
PROFESSOR OF HYGIENE AND PHYSICAL CULTURE IN AMHERST COLLEGE.

ALBERT D. HAGER, A.M.,
CHARLES H. HITCHCOCK, A.M.,
GEOLOGIST TO THE STATE OF MAINE.

IN TWO VOLUMES.

PUBLISHED UNDER THE AUTHORITY OF THE STATE LEGISLATURE,
BY ALBERT D. HAGER,
PROCTORSVILLE, VT.

VOL. I.

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NOTE.

The Principal of the Survey desires to state, that the publication of this Report has been entirely under the direction of Mr. A. D. Hager. In consequence of the great increase of the matter above the original estimate, the work has been a difficult one, and demanded not only much labor, but rigid economy, and great pecuniary responsibility and sacrifice. Yet, as the public will see, it has been carried through in excellent taste, and compares most favorably with the style of analogous Reports in other States. The citizens of Vermont are certainly much indebted to Mr. Hager for his faithful, judicious and persevering efforts — without which, these volumes never could have seen the light in a form so satisfactory.

It is but justice, also, to say, that Mr. Hager was fortunate in securing the services of the Messrs. Goddard, of Claremont, for the printing. Had they not possessed unusual skill in deciphering illegible manuscripts and correcting proofs, in some cases where from distance or other causes they had not passed under the eye of the authors, errors would have abounded where now we trust they are rare. And then the style of execution is highly creditable to the Claremont Company.

Equally fortunate was the selection of Mr. H. F. Walling, of New York, to execute the Plates, and Mr. John Bruen the Wood Cuts. Higher wages would, indeed, have enabled them to give them a higher finish; but for the prices agreed on, we think the execution highly satisfactory.

CONTENTS OF VOLUME I.

LIST OF PLATES

AT END OF VOLUME II.

LIST OF WOOD CUTS

IN VOLUME I.

[*For a continuation of Table of Contents, and List of Wood Cuts, the reader is referred to Volume II.*]

PRELIMINARY REPORT.

To His Excellency, Hiland Hall,

Governor of Vermont:

Honored Sir:

I have the pleasure of being able, at last, to lay before you a Final Report on the Geological Survey of the State. A few preliminary remarks from myself, as the responsible head of the survey, seem requisite.

The history of this survey has been so eventful and extraordinary, that a volume might be devoted to it, which would be full of moral interest at least. It startles one to find that the first movement on the subject was made in the General Assembly as early as 1836. In 1837, Governor Eaton, then Chairman of the Committee on Education, made his able report on the subject, which was never lost sight of till the first act, authorizing a survey, was made in 1844. Professor Charles B. Adams, the first State Geologist, entered upon his duties in March, 1845. He made four annual Reports, which, in the aggregate, formed a volume of 399 pages, with illustrations. In 1853 Professor Zadock Thompson was appointed to take charge of the work upon the decease of Prof. Adams. He never made any formal Report, though in other modes he brought out many facts, which were the result of his researches; and the outline of his proposed Final Report, published by Judge Young, shows how wide were his plans, and how valuable the final result would have been, had he lived. After his decease another attempt was made to carry forward the survey to completion, by the appointment of the Hon. Augustus Young, as its principal. His feeble health prevented Judge Young from much active labor in the field. But he published a valuable Report on the History of the Survey, in a pamphlet of 88 pages, and then he, too, died.

A fourth effort was made by the General Assembly to resuscitate and complete the work in the autumn of 1856, and I was requested to take charge of it. Meanwhile, during the following winter, another heavy Providential disaster fell upon the work, in the destruction by fire of the fine collections made by Prof. Adams and others: a ruin so complete, that probably not fifty specimens remain fit to take a place in the new Cabinet.

In view of so many calamities, I confess to have been somewhat affected by a feeling, which my judgment would call a superstitious fear, as if the frown of heaven rested upon the work, and that I too might expect to follow the triad of distinguished men who had been summoned away before the completion of the survey; especially as I knew my this time, since I have had charge of the survey, whatever analyses have been made, or in any way obtained by the Chemist, have been entirely gratuitous. But his time has been fully occupied in the geological part of the survey. Such has been the situation of my other son, EDWARD HITCHCOCK, Jr., that he has been unable to spend much time in the field, without making such sacrifices as could not be expected. He has done something, however, as will appear by our Report. We were so fortunate as to secure the services of Rev. S. R. HALL of Brownington, a well known assistant of Professor ADAMS, in connection with Professor THOMPSON, in the examination of the three most northern sections, and the collection of specimens. The results of his valuable labors will appear in our Report. I ought not to forget, also, the kind assistance rendered by Rev. C. A. WILLIAMS, who, not professing an acquaintance with Geology, joined us as an amateur, but ultimately rendered us important aid. Valuable facts and suggestions were also made to us by Rev. AUGUSTUS WING, of Stockbridge, a gentleman who has studied the Geology of the State with great perseverance and success. Nor can I omit acknowledging the many acts of kindness and generosity of JASPER CURTIS, Esq., of St. Albans.

I would not omit to express our great indebtedness to Prof. JAMES HALL, of Albany, the eminent paleontologist, for gratuitously naming the fossils in the collection, and describing the few new ones which have been discovered. We acknowledge our obligations also, for a like gratuitous favor, from Mr. G. F. BARKER, of Boston, in the careful and accurate analyses of numerous specimens, as the chemist's Report will show.

The first act, pointing out the duties of the Geological Surveyor, included Agricultural Chemistry and Geology, and the second act Natural History also. These subjects were omitted in the act under which I was appointed, and wisely in my opinion, for each of them deserves to be made the object of a separate survey; and then they will receive the attention which their importance demands. I trust that Vermont will not rest satisfied till both of them have been accomplished.

Physical Geography is named among the objects on which we were to report. But to this we have been unable to give much attention. Most of the mountains of the State have indeed been climbed by us, and their heights, too, measured by the Aneroid Barometer, as well as that of a multitude of other points on the surface. But the grand object of these measurements has been to be able to show the true form of the surface on the sections. To fix the latitude and longitude of particular spots, and delineate the topography, would require costly astronomical and geodetical instruments, and more than the whole time which we have spent in the geological survey. It would in fact be a trigonometrical survey, which we hope will be made in Vermont, but which we could not undertake.

The main objects which we have aimed to accomplish are the following:

1. To gain such a knowledge of the solid rocks of the State as to be able to delineate them upon maps and sections, according to the established system of geological science.

2. To study the loose deposits lying upon the solid rocks, and trace out the astonishing changes which the surface of the State has undergone; the whole forming what we call *Surface Geology*.

3. To collect, arrange and name specimens of rocks, minerals and fossils from every part of the State for the State Cabinet.

4. To obtain a full collection for the same Cabinet, of specimens valuable in an economical point of view; embracing many that are smoothed and polished.

5. To identify the metamorphosed rocks of the State with those that have not been changed. This last point has been the most difficult of all; and yet in a scientific respect, a very important one: indeed, it is so economically. For until we can determine the true character of the rocks, we cannot tell what useful substances we may expect to find in them and what ones we may not expect. And really, in my judgment, this is the most important use of a geological survey. It is not, as many suppose, to make discoveries of new substances that are useful, though this is occasionally done; but it is so to delineate the geological structure of the country, that practical men may be directed in their researches, and be saved from useless expenditures. Hence the value of a scientific description of the rocks, even of those parts that seem not to have much bearing upon the economical interests of a people: for we do know, that the most abstruse scientific principle often has a most important and unexpected practical application. On this ground it has been the practice in all our geological surveys to go into full scientific details. We do not feel that in such a state as Vermont, it is needful to apologize for trying to follow such an example, nor that its people will be satisfied with anything short of a careful scientific exposition of its Geology. With the means and time at our command, it has been quite impossible to go into each town and examine minutely its Geology. We have hoped only to be able to delineate the great features of the geological structure of the State, and thus prepare the way for minute surveys of each town, should the inhabitants wish it done. This work has already been commenced, and we shall append to our report one of these town surveys, executed by Mr. HAGER, by request of the people of Plymouth.

As to the character of the metamorphic rocks of Vermont, it is well known that eminent Geologists have not been agreed; that this has been a sort of battle ground for opposing theories. It so happened that neither I, nor my assistants, had ever taken sides in this contest, or had made up our minds concerning it. We have gone through with the whole work, quite indifferent which side would be favored by the facts we should bring to light. To use a common but expressive phrase, *we have gone it blind*, in all our researches. We have, indeed, been satisfied that a mighty wave of metamorphic influence has swept over the State from north to south, increasing in intensity as it advanced. But whether the facts we present favor one theory or another, we hardly even yet know. Our main desire is that the facts may aid in the development of the truth.

To carry out such a plan as above indicated over an area of more than 10,000 square miles, every one must see to be a gigantic work for less than three years; and we fear that it will be thought only imperfectly performed. I confess that such is the fact; but hope we have laid a foundation on which a finished superstructure will ultimately rise. The main labor of measuring the sections, collecting the specimens, tracing out the formations, and collecting the statistics of mines and quarries, has devolved upon A. D. HAGER and C. H. HITCHCOCK, who have been indefatigable in their labors during the summer, and also in the winter so far as was necessary. Mr. HAGER, in accordance with his own wishes, was requested to give special attention to the economical geology, that he might report upon it. C. H. HITCHCOCK was directed to give special attention to surface geology, so as to be able, if possible, to map the terraces: also to take full notes upon the extent, dip and strike of the formations, that he might be able to mark them on the Geological Map, and construct the sections:—a work which I wished done under my own inspection, and therefore more convenient for him than for Mr. HAGER, although the notes of the latter, as our Report will show, were essential to the work. So also, were those of Mr. HALL, as to the northern parts of the State. My elder son, E. HITCHCOCK, Jr., was directed to attend specially to the simple minerals and to the fossil mammals of the post-tertiary strata. He will, however, make no separate report, but merely describe these objects in their appropriate places in the general Report.

This Report, which I have now the honor of laying before your Excellency, will be made up of the following parts:

1. I would request that this preliminary letter from myself may stand at the head.

2. Report on the Scientific Geology. This will be the joint work of myself and assistants, because all have been concerned not only in collecting the facts, but in describing them. I have, indeed, taken a leading part in the preparation of this report, but I have been dependent upon others for the details and most of the illustrations, and some of the leading descriptions. And in order that justice should be done to each one, I have attached the initials of my assistants' names to each of their contributions. Nay, where any facts have been referred to, as for instance, the dip and strike of strata, I have given the initials of the individuals who furnished them, whether one of my assistants or a previous geologist: for instance, C. B. A. for Prof. ADAMS; Z. T. for Prof. THOMPSON; A. D. H. for A. D. HAGER; and C. H. H. for CHARLES H. HITCHCOCK.*

3. Report on the Economical Geology, by A. D. HAGER. The facts in this report have been mainly collected by him.

4. Report on the Chemistry of the Survey, by CHARLES H. HITCHCOCK. This brief report embraces all the chemical analyses that have been made from the beginning of the survey under Prof. ADAMS, amounting to over one hundred. Of these, about forty have either been made or obtained during the present organization of the survey. Yet, as stated elsewhere, no money has been expended for them: they are all gratuitous.

5. Catalogue of 2800 specimens of rocks, 370 specimens of simple minerals, and several hundred specimens of organic remains collected by the present geological corps; all of which have been arranged, ticketed and named, and are displayed in the State Cabinet. Great care has been taken to make the specimens just three inches square, where it was possible; and my assistants have been very successful in this operation; and as arranged in the new State House, according to my suggestions in my last Report, with the several Sections drawn above them, they present a very clear exhibition of the Geology of the State to every spectator. The Economical Collection has not yet been catalogued.

6. Report of Rev. S. R. HALL, specially on the three northern Sections, with a Report on the Agricultural Geology of the State. It is very gratifying that this gentleman, who, as assistant geologist, begun a systematic exploration of the geology of the State fifteen

* By such a course each member of the survey is responsible only for the facts he has stated and the opinions he has advanced. We agree in all the great principles of geology; and, so far as I know (for I have never made the inquiry), on every point discussed in this Report. Yet it would be strange, if on some of the difficult questions raised, as to the position, equivalency and metamorphism of the Vermont rocks, there should not be among us some diversity of views. If there is, each member of the survey is responsible only for his own opinions which are given over his own name.

years ago, and much earlier as an amateur, should have been willing to take up the work again, and especially explore the north eastern part of the State where the reign of the wild animals has hardly yet been much disturbed by man. And though my commission did not require any attention to Agriculture, I felt confident that some remarks on that subject from one so competent would be acceptable.

In conclusion, allow me to express the hope, that though the people of Vermont may not realize all they had anticipated from this long protracted survey, yet when they look over the large array of facts which we now present, respecting the subterranean resources of the State, and see how many questions of deep scientific interest are here started and in part resolved, and how wonderful and even sublime have been the changes which the solid frame-work and the surface have undergone, they will feel that they have some return for their patience and perseverance in carrying the work through. As to myself, every year has deepened my impressions of the amount and value of the mineral resources of the State, and of the scientific interest connected with its Geology. The rocks of Vermont are the most difficult with which I have ever attempted to grapple; but they have taught me many a valuable lesson: and as to their economical value, I have been impressed with the following facts:

First and most important of all, we think we have discovered the reason why Vermont so excels all the other New England States in the agricultural capabilities of its soil. It is the existence, in almost all of her rocks, of lime in such a state that natural processes bring it out in just about the quantity needed by vegetation. This is the case in many parts of the State where the inhabitants hardly suspect the existence of lime, and those parts of the State most fertile are just the places where lime is most abundant and decomposable. This is a treasure which Providence has hidden in the earth and provided for its elimination at the right time and quantity, and it is of far more value in my estimate than all the other subterranean wealth of the State, yet I had no suspicion of its existence and use till a late stage in this survey, excepting on the west side of the Green Mountains.

Secondly, most of the valuable rocks and minerals in Vermont run lengthwise of the State, and are thus made accessible to most of the inhabitants. This is the case with the granites, the marbles, the slates, the soapstones, the serpentines, the iron and the gold, to say nothing of others of less value.

Thirdly, these mineral treasures are inexhaustible in quantity.

Fourthly, they are of such kinds as will always be in increasing demand all over the country, as its population increases.

I cannot, therefore, but look upon Vermont as a giant whose full proportions and strength are yet in a great measure undeveloped; and in this, which is probably my last literary labor, I cannot but pray that God would continue to prosper and bless a State so strong by nature and so rich in noble institutions!

Most respectfully submitted,

EDWARD HITCHCOCK.

AMHERST, Oct. 1, 1859.

The publication of the Report having been delayed, it became desirable that a brief preliminary Report should be made to Governor Fairbanks in 1860. Some extracts follow:

To His Excellency, Erastus Fairbanks,

Governor of Vermont:

Honored Sir:

It did not occur to me till recently that any Report on the Geological Survey of the State would be expected or desired the present year; for, last year I presented our Final Report, though in an imperfect and unfinished state. It was referred to the Secretary of State, who was directed to obtain estimates of the cost of its publication. The Report itself was put into the hands of its authors, viz: myself and son, Mr. Hager, and Rev. Mr. Hall. We have been at work upon it and are still at work to supply its deficiencies, incorporate whatever new facts and discoveries we might obtain during the year, and reconstruct many of the Maps and Drawings, for economy's sake. We have done all we could to help the Secretary in making out his estimates, which I trust by this time have been presented to the Government.

By the original act constituting the Survey, it becomes my duty annually to present a summary of the expenses and needs of the work. Perhaps the following brief summary, which reaches back to the commencement of our connection with the survey, may be acceptable:

Traveling and Freight Expenses	in 1857,	$ 332,10
do.	in 1858,	$ 737,25
do.	in 1859,	$ 188,00
do. (rough estimate)	in 1860,	$ 200,00
	Expenses,	$ 1457,35
Received $ 1000 per year in 1857, 1858, 1859 and 1860,		$ 4000,00
	Salaries,	$ 2542,65

The salaries over and above the expenses have been distributed as follows: My oldest son Edward, having been prevented by circumstances from spending more than a few weeks in the field, charged nothing save his expenses. For the first two years I charged nothing, because it seemed to me reasonable that what money remained above the expenses, should be shared by my two assistants, Mr. Hager and my youngest son Charles H., who from the beginning have labored indefatigably in this work.

In 1857	Mr. Hager received	$ 333,95
In 1858	do	$ 131,37
In 1859	do	$ 256,00
In 1860	do	$ 266,67
		$ 987,99

In 1857	Charles H. Hitchcock received	$ 333,95
In 1858	do.	$ 131,37
In 1859	do.	$ 256,00
In 1860	do.	$ 266,67
		$ 987,99

In 1859	I received	$ 300,00
In 1860	do.	$ 266,67
		$ 566,67

In the expenses above mentioned are included *seventy five dollars* paid Rev. S. R. Hall, for services in the survey.

In regard to the future, I am happy to say that *we have no further charges to make.* Should the Government publish our Report, it will indeed require a good deal of labor on our part. But we shall lay no claim to remuneration. Our explorations during the past season have brought to light several facts of much scientific interest, which we have incorporated in our Report. Mr. Hager, also, at his own expense, has secured a number of photographic sketches of the scenery of the State, which he is willing to attach to the Report, with descriptions, if the Government are willing to order them lithographed. They would undoubtedly add much to the interest of the Report.

Respectfully submitted,

EDWARD HITCHCOCK.

Amherst, Mass., Oct. 22, 1860.

GENERAL PRINCIPLES

OF

GEOLOGY.

THE time has not yet arrived, when we may presume that the fundamental principles of Geology are so well understood by the community in general in our country, that no preliminary statements are necessary in a Report intended for general circulation. In the present instance, however, we may be brief. For, in the first place, a large space was devoted to an elucidation of the science in the early Reports on the Vermont Survey by Prof. ADAMS; and secondly, we have a right to presume upon a great increase of general acquaintance with the subject since that time. Nevertheless, the science has made no little advance within twelve years, and there are certain points which are intimately connected with Vermont Geology, that are only now in a course of development by geologists, and will, therefore, need special attention.

STRATIFIED AND UNSTRATIFIED ROCKS.

It is not mere hypothesis, but legitimate theory, which leads geologists, with almost no exception, to the belief that the interior of the earth is now in a molten state, and that at an early date it was entirely melted. But being placed as the earth is, in a medium (the planetary spaces) from 50° to 75° below zero, a crust must have formed over the molten surface, which has been growing thicker up to the present time. This envelope is called *the crust of the earth.* Geological facts would lead to the conclusion that it cannot be more than a hundred miles thick; but some astronomical reasoning, which we regard as less satisfactory, increases the thickness to six hundred miles.

Now the rocks of this crust are found to be of two kinds, the Stratified and Unstratified. The former are composed of layers like a pile of boards or books, lying upon one another; though the layers are sometimes curved more or less. Each stratum is also subdivided into extremely thin layers, like the leaves of a book, generally, but not always parallel to the planes of stratification, called *laminæ* in the mechanical deposits, but *folia* in the schists. The slates have another set of divisional planes coinciding more or less with the beds or strata in direction, called *cleavage* planes, most obvious in common roofing slate. A third set of parallel planes cross the strata in at least two directions, dividing the rock into rhomboidal forms, and called *joints.*

The unstratified rocks have no parallel divisional planes, except that sometimes they are jointed, regularly or irregularly. But lamination is always, and cleavage generally absent. This class of rocks are thought always to have been melted by dry heat, or made plastic

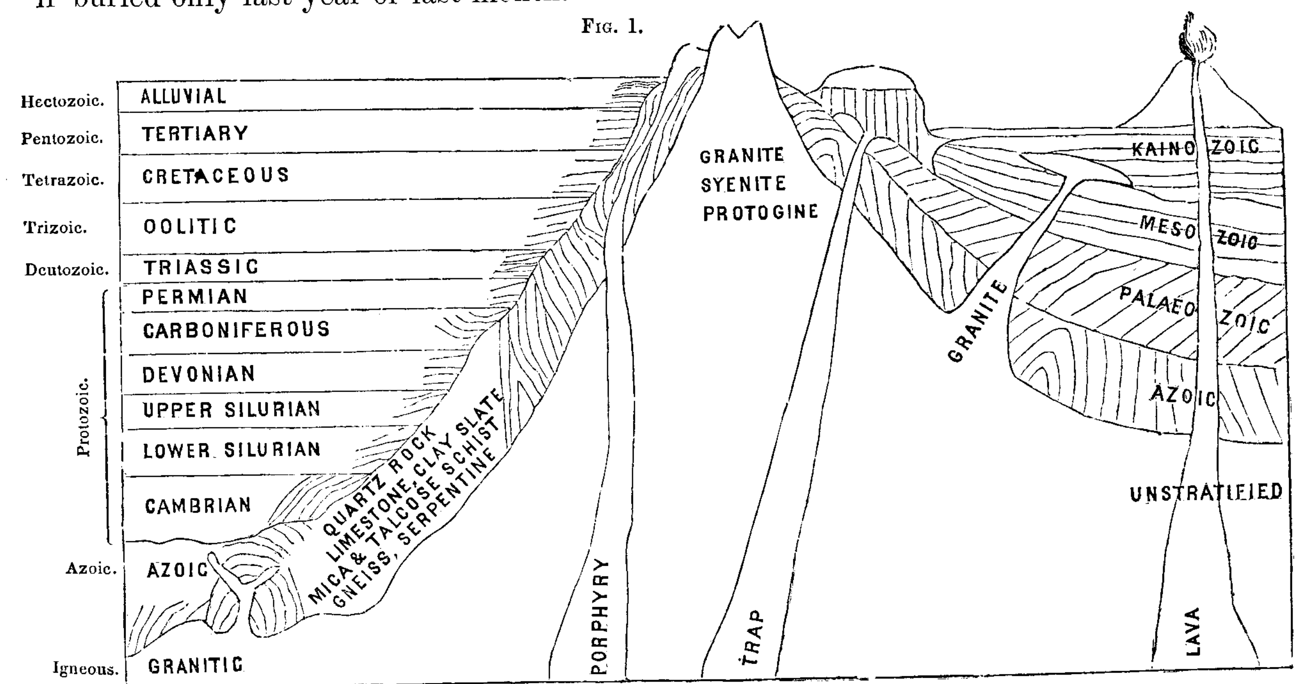
by hot water. The stratified rocks are believed to have been deposited in and by water, as strata and laminæ of sand, gravel and clay, are now forming in rivers, ponds, lakes, and the ocean. But they have subsequently been subject to cleavage and foliation; and only a small part of the stratified rocks lie in a horizontal position. The lowest, that is the oldest, as a general fact, are most raised or tilted up; some indeed stand perpendicular. Some of the newer or uppermost strata are horizontal. This shows that the tilting process was subsequent to the deposition, and in most cases to the consolidation of the formations, and that it took place at different times, so as to give the lowest the largest dip.

A difference as great exists in the consolidation and structure of rocks. The very newest consist of unconsolidated gravel, sand, and clay, forming alluvium. A little farther down we come to the tertiary strata, some of which are hardened into rock, and others are more or less loose and soft. Next below the tertiary we find thick deposits, mostly consolidated, but showing a mechanical structure along with a crystalline arrangement of the ingredients. These are called secondary, and transition; though these terms, especially the last, are getting out of use. Lowest of all we find rocks having a decidedly crystalline structure, looking as if the different minerals of which they are composed crowded hard upon one another. These rocks are called Metamorphic, Hypozoic, and Azoic.

FOSSILIFEROUS AND UNFOSSILIFEROUS ROCKS.

The term Fossil is extremely difficult to define. Upon the whole we prefer that definition which represents a fossil to be the body of an animal or plant, or any part thereof, or even any trace of the same, such as a mould, or footmark, *buried naturally in the earth.* Such bodies or impressions are called organic remains, and if changed to stone, petrifactions. By this deposition a body may be a fossil, and possibly a petrifaction, even if buried only last year or last month.

FIG. 1.



Ideal Section of the Earth's Crust.

Now we find in descending into the stratified rocks that they abound in fossils to the depth of at least ten miles, and these are called fossiliferous; but in all the rocks below, which are mostly crystalline, of unknown thickness, no organic remains occur, and these are called unfossiliferous. Neither do they occur in the unstratified rocks.

The adjoining section of a portion of the earth's crust will give a better idea than verbal description, of the relative position of the stratified and unstratified rocks of the fossiliferous and un-fossiliferous, of their thickness in Europe, of the relative position of the unstratified and the stratified, and the names of the principal Formations and Groups in both classes. Such a section cannot indeed be found at any one locality, but all the facts are obtained at different localities and here combined into one view.

SURFACE GEOLOGY.

Surface Geology embraces those erosions of the earth's surface which have taken place since the consolidation of its crust, and all those depositions of the abraded materials which have taken place since the tertiary period. The amount of this erosion by the ocean, the rivers, icebergs, glaciers, rains and the atmosphere, has been immense, exceeding in some parts of Great Britian, 10,000 feet, and not less probably in our country. The materials worn off before the tertiary period have been mostly consolidated into the Palaeozoic, Mesozoic, and Kainozoic rocks: but since that period they have been spread over the valleys and cavities as loose deposits.

The earliest of these post-tertiary deposits were generally very coarse and scarcely stratified, having been carried from high latitudes towards the equator, and are called Drift. Subsequently a part of this drift has been acted upon by ice and water, more or less comminuted, and re-deposited with a more distinctly stratified and laminated arrangement upon the drift. This is called modified drift. Genuine drift, however, has continued to be produced by icebergs, glaciers, mountain slides, and rivers, up to the present time. But the period immediately succeeding the tertiary was the time of its most abundant production, and has, therefore, received the name of the Drift Period. The formation is mainly an earlier member of Alluvium.

Drift and Modified Drift form some of the most striking and interesting features in the geology of Vermont.

PALEONTOLOGY.

Paleontology is the science of fossils, or organic remains. It opens a marvellous history of the ancient races and peculiar forms of animals and plants that once lived on the globe. A few statements only of the leading conclusions of the paleontologist can here be given.

1. The number of species of animals and plants dug out of the rocks and described up to the present time, cannot be less than 35,000, 2750 of which are plants. In 1849 Dr. H. G. Bronn gave a catalogue of 26,421 species of animals and plants, distributed through the formations as follows:

1. *Lower and Upper Silurian, Devonian, Carboniferous, and Permian;* one great life period.
Thickness of the rocks, over 50,000 feet.

Plants,	1183
Radiated Animals,	768
Mollusca, or Shells,	2708
Articulated Animals,	641
Vertebrate Animals,	328

2. *Triassic Formation.*

Plants,	115
Radiata,	150
Mollusca,	776
Articulata,	22
Vertebrata,	143

3. *Oolitic, or Jurassic Formation.*

Plants,	355
Radiata,	626
Mollusca,	2332
Articulata,	382
Vertebrata,	552

4. *Cretaceous Formation.*

Plants,	122
Radiata,	1581
Mollusca,	2817
Articulata,	177
Vertebrata,	241

5. *Tertiary Formation.*

Plants,	945
Radiata,	2081
Mollusca,	7913
Articulata,	1828
Vertibrata,	1557

6. *Alluvial Formation.*

Plants,	31
Radiata,	12
Mollusca,	126
Articulata,	2
Fishes,	2
Reptiles,	9
Birds,	55
Mammals,	219
Lithichnozoa,	20

7. *Living Species.*

Plants,	69403
Radiata,	4818
Mollusca,	11482
Articulata,	67360
Vertebrata,	18085

2. Each rock formation is characterized by its peculiar group of fossils not found in any other, so that a paleontologist on seeing a specimen can usually tell from what part of the series it came.

3. The preceding list of species will show that all the great classes of animals and plants have their representatives in nearly all the formations, though no vertebral animals are found and no flowering plants in the lower silurian group. Indeed the plants and animals lowest in organization are found in the oldest rocks, and the more perfect ones have been gradually introduced, so as to make those now living the most perfect of all.

4. The new races have been introduced not by the gradual change of one species into another, but by the creation of new and successive groups. The earth has changed its inhabitants entirely five or six times. Indeed some eminent writers reckon as many as twenty seven life periods, each having its peculiar fauna and flora.

5. Excepting a few hundred species in the alluvial and tertiary rocks, no living species of animals or plants are found fossil. Below the tertiary every species has died out, although the classes and families, and sometimes the genera, extend through the whole series.

6. The fossil species, even those in high latitudes, correspond more nearly with those now living between the tropics than in the temperate or frigid zones; proving that the climate, when the fossil species lived, must have been tropical or even ultra-tropical.

7. Not a few of the fossil species had forms quite peculiar and anomalous, exhibiting characters now found only in different classes; yet they were only peculiarities wisely adapted to the condition of a changing world, and all belonged to that one great system of organic beings, which embraces and links together all the minor systems of life both living and fossil.

METAMORPHISM OF ROCKS.

We suppose that every geologist considers it a settled principle, that all the rocks accessible to man have undergone entire and most of them repeated changes of form and character since their original creation. If the globe was once in a molten state, the crust which first formed over its surface must have been some kind of unstratified rock. When it became cool enough to allow water to condense on the surface and form oceans, the waves would wear away portions of the rock and deposit the fragments in the form of gravel, sand, and clay. These by the action of internal heat might be hardened and become conglomerates, sandstones and shales. If new beds of materials should be thrown down upon these strata, it would cause the internal heat to penetrate farther upward into the conglomerates, sandstones and shales, and by the help of water render the rocks plastic and convert them from mechanical into crystalline rocks, without destroying the planes of stratification, though generally obliterating all traces of organic structures which they might have contained, and changing the laminated structure into foliation and cleavage. After all this, water may have acted mechanically on these strata, wearing them away and forming other deposits of pudding stones, sandstones and shales. Meanwhile, also, the internal heat, working farther upward, as it certainly would do by the accumulation of new beds of detritus, might melt over the lower beds of the strata, converting them into unstratified rock. And thus might the same materials have been subject to repeated and most thorough metamorphosis.

We do not feel justified in dismissing this subject with such general views. For so intimately is metamorphism connected with the rocks of Vermont, and so much is it illustrated by them, that they cannot be understood without an accurate knowledge of metamorphism ; and science demands that we should describe whatever facts have fallen under our notice that will throw any light upon so difficult a subject. It is one of those points in geology about which its ablest cultivators still entertain considerable diversity of opinion. Though we scarcely had any opinions concerning it when we began the examination of Vermont, we have been gradually compelled, by the facts, to adopt in the main the views so ably put forth and defended by such writers as Bischof, Lyell, Hunt, Jukes and others. Some of these views are so recent that they have not found their way into many of our elementary treatises on geology, and we judge it desirable that we should state the general principles of metamorphism, especially as the rocks of Vermont furnish us with some facts that, so far as we know, have not been before brought out, except in a little work on Elementary Geology which we have recently published. New and important facts have come under our notice within a few days (Sept. 1860), which we shall combine with the statements in that work, whose language we shall employ where we cannot alter it for the better.

We regret the necessity of using many technical phrases, and of presuming upon a good deal of acquaintance with geology, in the readers of this part of our Report. Any who choose, can pass it over till they have read the details of Vermont geology in the subsequent pages, when this part will be more intelligible.

The metamorphism of a rock in its widest sense, is its transformation from one kind into another. Consequently it takes place after the original formation of the rock.

The term "Metamorphic Rocks" has been used by Sir Charles Lyell and others in a much more limited sense, to designate a class of rocks (mica schist, talcose schist, gneiss, &c.), that have been so transformed as to have become crystalline, and to have lost for the most part their original structure. But this is only one case of metamorphism. Prof. John Phillips, also, limits metamorphism to rocks that have been altered by heat ; whereas it appears that water and other agents have played quite as important a part in the change as heat.

AGENTS OF METAMORPHISM.

Heat is a most important agency, and a certain degree of it is probably indispensable; and yet other agencies effect important transformations of rocks at a temperature not above that of the atmosphere generally. Yet the most striking examples of metamorphism were first observed in the vicinity of trap dikes, where chalk was changed into crystalline limestone, clay into clay slate and mica schist, and fossils were obliterated. Hence it was natural to suppose that wherever such effects were seen, dry heat had been the cause, since the trap dikes were regarded as having been once in a melted state. But it has been found that other agencies might be concerned even in the case of dikes.

Water is one of these agents. It acts in two ways; first in connection with heat, secondly by its power of dissolving all rocks, and as the carrier of chemical re-agents to aid in the work. There is a third mode in which it sometimes prepares the way for chemical metamorphic action, viz. by freezing in the minute fissures of rocks, and thus opening them to the influence of decomposing agencies.

Professors W. B. & R. E. Rogers subjected 48 species of silicious minerals, rocks, glass, porcelain, &c., to the action of pure water, and of water charged with carbonic acid. The minerals and rocks were such as feldspar, hornblende, augite, schorl, mica, talc, chlorite, serpentine, epidote, dolomite, chalcedony, obsidian, gneiss, greenstone, lava, &c., and the result was, that all of them were acted upon by the carbonated water, and in a slight degree by pure water. Quartz was not among them. This in a pure state is absolutely insoluble by water, or by any acid, save the fluoric. There is a form of silica which is soluble, and if it be converted into silicates, as in most of the minerals used by the Professors Rogers, it is soluble, and is found in most mineral waters. The decomposition of these silicates is accomplished in a variety of ways, and usually leaves an excess of silica in a free state, which forms quartz.

How deep water penetrates into the crust of the earth we know not. But we know that it possesses an astonishing power of working its way into fissures and pores. Especially when converted into steam and kept in by strong pressure, we can hardly set bounds to its interpenetration. We know that rocks deposited in water are several miles thick, and in some of them water is chemically combined.

We might suppose that the increasing heat, as we descend into the earth, would expel all the water, or at least drive it near the surface. But the phenomena of volcanoes lead to a different conclusion. The immense quantities of steam that are poured forth from the craters demonstrate the presence of water at a great depth, as do the eruptions of mud, called moya, in South America and in the Caucasus, and which in one volcano in Java became a river of mud and diluted sulphuric acid. But the most remarkable fact of all is, that ejected molten lava probably owes its liquidity to water. When a stream of it is poured forth, steam escapes from the surface, and a crust is formed in consequence, which prevents the escape of the condensed steam within, except when cracks are formed; and hence the fluid state is preserved within for a long time; nor till that has escaped will it be consolidated; so that in the opinion of some of the ablest writers on volcanoes, such as Scrope, liquid lava is an aqueo-igneous fusion. The heat is found to be not high enough to produce liquidity without water.

Suppose now the water in the stratified rocks to be highly heated, and yet essentially imprisoned by impervious strata at the surface; it is easy to conceive that it might reduce the rock to a fluid or semifluid condition, without destroying the planes of stratification, or producing a complete fusion like that of lava. In that state such chemical changes might occur as would give a crystalline structure, form new simple minerals, and produce planes of cleavage, foliation, and joints.

But though hot water and steam would produce powerful metamorphic effects, they would be very much increased if we suppose that water to contain in solution chemical agents of great power; for instance, carbonic, sulphuric and muriatic acids, sulphureted hydrogen, and alkaline carbonates. There is no rock, except perhaps pure quartz, that could withstand their combined action. They would all be softened and made so plastic that in the course of centuries all the changes exhibited by metamorphic rocks might be brought about.

We have a very striking example of such agencies, in the account given us by Forest Shepherd, Esq., of "the Pluton Geysers of California." These are hot springs, which throw out intermittingly and spasmodically, powerful jets of steam and scalding water; their temperature varying from 93° to 169° Fahr. Sulphuric acid and sulphureted hydrogen at least, according to Mr. Shepherd's account, are present, and probably other energetic ingredients. Says Mr. Shepherd, "You find yourself standing not in a solfatara, but in one of the salses described by the illustrious Humboldt. The rocks around you are rapidly dissolving under the powerful metamorphic action going on. Porphyry and jasper are transformed into a kind of

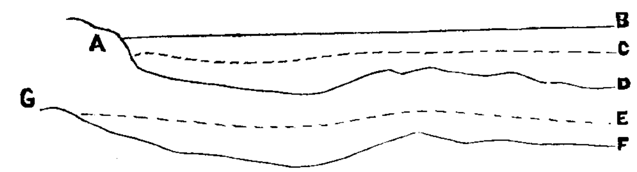
potter's clay. Pseudo-trappean and magnesian rocks are consumed, much like wood in a slow fire, and go to form sulphate of magnesia and other products. Granite is rendered so soft that you may crush it between your fingers as easily as bread unbaked. The feldspar appears to be converted partly into alum. In the meantime the bowlders and angular fragments brought down the ravine and river by floods, are being cemented into a firm conglomerate, so that it is difficult to dislodge even a small pebble, the pebble itself sometimes breaking before the cementation yields." Mr. Shepherd adds: "The metamorphic action going on is at this moment effecting important changes in the structure and conformation of the rocky strata. It is not stationary, but apparently moving slowly eastward in the Pluton Valley." (Am. Journal Sci., Vol. XII., N. S. pp. 157, 158.)

This spot seems to be an opening into the great laboratory of nature, where we get a glimpse of the mighty works she has been carrying on in almost every part of the earth's crust during the past geological ages. We have reason, however, to believe that the action was more powerful in past times than at present, because the earth's crust was thinner, and volcanic agency more common and energetic. Yet at the Pluton Geysers it is energetic enough, and that too at a very moderate temperature, to melt and transform all known rocks, unless it be pure quartz.

But though a very high degree of heat does not seem to be necessary to most cases of metamorphism, yet it is essential that there should be an increase of it in newly formed strata, that they may be changed: and how may we suppose this to have been accomplished?

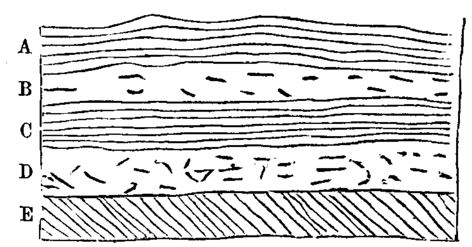
An eminent mathematician, Prof. Babbage, in 1834, proposed a theory to show how the surfaces of equal temperature within the earth's crust might experience changes in a vertical direction. Thus suppose A B (Fig. 2), to be the ocean's surface, and A D its bottom, rising into a continent above A. Let G F be a line of equal temperature, say two miles below the ocean's bed, which line would be essentially parallel to the surface. Let now the accumulations of sand, clay and gravel, which are constantly going on in the ocean, raise its bottom to A C. This coating of non-conducting materials would prevent the escape of the heat, which rises from the heated interior, and cause it to accumulate at a higher level, so that the isothermal G F (line of equal temperature) would rise to G E—that is, as high as the bottom of the ocean had been filled. The increase of heat might be sufficient to produce the metamorphisms which we find many of the stratified rocks to have undergone.

Fig 2.



Another consideration deserves to be taken into the account. Different beds of rock require for their fusion, or semifusion, very different degrees of heat. Hence heat permeating upward through the successive beds A B C D E (Fig. 3), might almost entirely melt some (D), partially fuse others (B), obliterate the fossils in one (E), and leave them more or less distinct in others (C and A.) This is exactly what we find in the earth, and what we might expect in theory.

Fig. 3.



Another fact may be explained on the same principles. If we examine a rock formation over its whole horizontal surface, we shall find sometimes that it has undergone very different degrees of metamorphism in different parts. In one portion of the field we find that the original rock has been transformed into gneiss, and in another into mica schist (as in the Hoosic Mountain range in Massachusetts), in another part (as in Canada) but little altered, and containing organic remains. The statements above made show us how these different degrees of metamorphism might have occurred, either by the different degrees of fusibility in the materials, their different composition, or the greater or less amount of heat introduced into them.

The above facts and reasonings authorize a more sweeping conclusion, viz. that almost every rock is capable, by metamorphism, of being converted into almost any other. It is usual to suppose that we are to find in the metamorphic rock only the ingredients that exist in that from which it was derived. But if the latter be made plastic by aqueo-igneous agency, why may not the water present contain other ingredients not in the original rock? And who can set limits to the varieties of rocks that might then be produced?

In view of such facts, also, we can readily assent to Bischof's conclusion, when he says, "The mineral kingdom, therefore, contains nothing that is unchangeable, unless perhaps it be the noble metals — gold and platinum."

A third important agency in metamorphism is the atmosphere. Its four constituents, nitrogen, oxygen, carbonic acid, and aqueous vapor, all act upon the rocks, not merely at the surface, but by means of water they are carried deep into the earth, and furnish probably a large part of the chemical agents that are active in metamorphism. Thus nitrogen and oxygen uniting, form nitric acid, and nitrogen combining with the hydrogen resulting from organic changes, forms ammonia; and both of these agents, nitric acid and ammonia, carried by water into the crust of the earth, form very energetic agents of change, we know not how deep. Carbonic acid, also, is soluble in water, and is thus introduced among the rocks, which it dissolves by direct action and by uniting with other ingredients to form other re-agents. There is enough in the atmosphere to contain 2,800 billion pounds of carbon, and this carbon acts as a carrier of the atmospheric oxygen, first introducing it among the plants and rocks as carbonic acid, and leaving it by other combinations to escape again. These atmospheric agents operate quietly, but the amount of disintegration exhibited almost everywhere by the rocks shows that the work is a mighty one. The atmosphere, which, as we breathe it, seems so bland and inefficient, is in fact silently crumbling down the solid rocks — we know not how deep — with a power compared with which the efforts of the quarryman and the miner are mere infinitesimal blows.

A fourth metamorphic agency at work in the earth is galvanism. All chemical changes do, indeed, imply the presence of this force: but we know of no other agency which in rocks but partially plastic could transfer ingredients from one part of the mass to another, as seems to have been done, and to be now doing. Thus, a vein of copper ore has been divided by a transverse crack so that the two ends were separated some inches. But the fissure was subsequently filled with sand; and after some years it was found that the vein was continued across the opening by the introduction of copper ore. Again, how, but by galvanism, can we explain the production of cleavage, foliation, and joints? These have required a polarizing force, and galvanism is such a force.

FORMER PLASTIC CONDITION OF THE ROCKS.

Such are the chief agents of metamorphism. Let us now proceed to consider the most important effects they have produced in the rocks.

In the first place, they have brought most of the stratified rocks into a plastic or semi-plastic condition, subsequent to their original consolidation, and continued them in that state for a great length of time.

This position seems to us to lie at the foundation of metamorphism. Yet as it is not advanced in elementary treatises upon geology, as a principle capable of proof, we find it necessary to bring out that proof; especially as the rocks of Vermont furnish some remarkable evidence on this point, and, so far as we know, entirely new.

We proceed on the supposition now generally admitted by geologists, that all the stratified rocks were originally deposited from water and subsequently consolidated into shales, sandstones, conglomerates, and fossiliferous, earthy and compact limestones. Though the fragments have been cemented together by chemical agency, yet they still retain, after consolidation, the evidence of the mechanical forces by which they were crushed, comminuted and rounded.

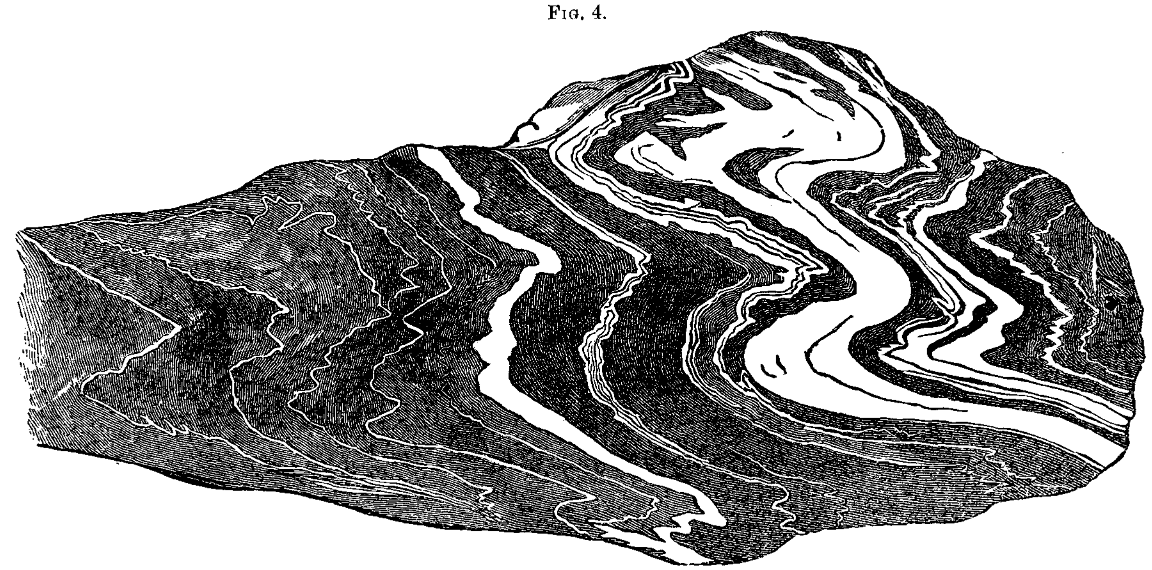
But if we start with such rocks, which manifest so much of mechanical and so little of chemical agencies, and run back to the most highly crystalline, we shall find a series of changes which indicate a plastic condition subsequent to consolidation; a degree of plasticity sufficient to allow of movements among the particles, and of course great chemical changes, but not generally so complete a fusion as to obliterate all traces of original deposition and lamination; nor, in some cases, of the mechanical origin of the materials. We present the following proofs of such plasticity:

1. Their texture has been more or less changed from mechanical into crystalline. We find the process indeed in all its stages, and this enables us to prove that it has actually taken place.

2. The organic remains in these rocks have been sometimes elongated, or otherwise distorted, so as it could have been done only while in a plastic state. More often these remains have disappeared entirely, and a crystalline texture has supervened. This could have been done only by chemical agency, while the materials were in a yielding state. For a change of crystallization can take place only where the particles are free to obey the laws of molecular action for bringing them into new positions.

3. The strata and folia of rocks now highly crystalline, have been subject to remarkable foldings and distortions, such as only a plastic state of the materials will explain. Fig. 4 represents a bowlder of gneiss and interstratified hornblende schist, obtained from the bed of Deerfield river at Shelburne Falls, in Massachusetts, a few miles south of the Vermont line, but well representing many spots in the latter State. Few geologists will doubt that mechanical pressure must have produced the beautiful curvatures of the layers.

Fig. 4.

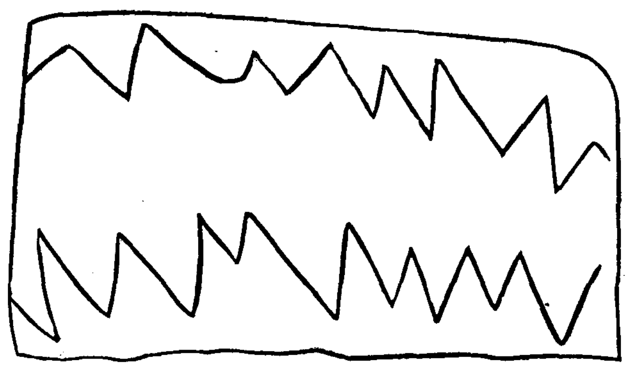


Plicated Gneiss.

It may, indeed, be supposed that the folding took place when the materials were in the form of clay. But it is doubtful whether such great perfection in the curvatures could have been produced in clay, and retained through all the subsequent changes which have resulted in a highly crystalline condition. Moreover, some of the foldings in this rock have an angular sharpness which we have never seen in clay, as in the subjoined sketch, in Fig. 5, taken at the same locality; and indeed the specimen exhibited on Fig. 4 shows to the eye a multitude of such serratures, too minute to be marked on the drawing. They seem to be the result of strong pressure on fine folia of rock, having somewhat of stiffness, so that a lateral force would crumple it up rather than produce regular curves.

Some writers (e. g. Tyndal on the Glaciers of the Alps, p. 9) maintain that all such foldings of the solid rocks might result from "ages of pressure" upon them without softening. But it is not mere curvature that is to be explained, but crystallization; and this could take place only where the mass was soft enough to allow of a movement of the molecules.

Fig. 5.



4. Some of the phenomena of granite veins and trap dikes are explained with difficulty, unless we suppose a plastic or semi-plastic condition of the rocks through which they pass.

Some of the granite veins that have been usually regarded as veins of injection, are so tortuous that the idea of their having been filled in their present form by the intrusion of melted rock, is absurd. For the projecting films of rock, sometimes not more than a quarter of an inch thick between the folding of the vein, must have been broken off. We shall give one or two sketches of such when describing granite, though such sketches convey no adequate idea of these cases. We conceive that after these veins were introduced into the rocks in the wet way rather than by injection, the folia were crumpled up so as to produce extreme tortuosity, and this would require plasticity.

Trap dikes are sometimes introduced into such rocks as the schists and gneiss, and where they are dislocated the broken extremities are so implanted in the folia as could have been done only by materials in a semi-plastic condition. But without drawings we cannot make this point intelligible, and we can only refer for an example to the Elementary Geology above mentioned, as illustrated by its 142d figure.

The great number of veins that sometimes form a delicate net work, can be explained only by a plastic condition of the rocks, allowing the veins to be segregated or injected. This is finely illustrated by the veins of calcite interlaced in limestone and clay slate along the shores of Lake Champlain. The pebble shown on Fig. 226 will give an idea of such veins. The beautiful brecciated red marble wrought in the vicinity of Burlington also clearly indicates a plastic condition of the base. The red angular fragments seem to have floated in the matter of the veins.

5. *We have found striking examples where the pebbles of conglomerates have been elongated and flattened so as at length to be converted into the silicious folia of the schists, and the cement into the mica, talc and feldspar.*

This we regard as the most decisive evidence we have met of the former plasticity of all the schists and of gneiss. But as we have never seen any description of such metamorphoses, and it is only till within a few days that we have become fully possessed of the facts (October 1860), and moreover other geologists may demur to our conclusions, we deem it necessary to go into greater detail than would otherwise be necessary. In a Report on the Geology of Massachusetts made in the year 1833, a singular conglomerate was described near Newport, R. I., "composed of elongated rounded nodules of quartz rock and quartz rock passing into mica slate with a cement of talcose slate: the nodules varying from the size of a pigeon's egg to four and even six feet in their longest diameter; and so arranged that their longest diameters are uniformly parallel to one another, lying in a north and south direction." The conglomerate is divided by fissures running east and west perpendicular to the horizon, and parallel to one another, from 10 to 20 feet apart. These fissures divide the thick masses of conglomerate so perfectly that they seem as if cut through by the sword of some Titan. The nodules through which the fissure passes, are divided very neatly, and the parts present even surfaces, so as to give the rock quite a peculiar aspect."

These facts were repeated in the subsequent Reports in 1835 and 1841 upon Massachusetts. But it was not till we found an analogous conglomerate at intervals along nearly the whole western side of the Green Mountains, that the special bearing of the facts above mentioned upon metamorphism occurred to us. Two of us then (1859) visited Newport to get a clearer view of the facts, in the hope that they would help us unravel better the intricacies of the Vermont conglomerates. One of us that same year gave a paper on the subject before the American Scientific Association, as it was developed at Newport and at East Wallingford, where an interesting locality had been discovered by one of our number (A. D. Hager). In 1860 another of our number (C. H. H.) brought the subject again before the Scientific Association. But it was not till since that time that the last link in the argument was supplied by a visit to a locality in Plymouth, Vt., which was also discovered by A. D. Hager. We will try now to state the facts and conclusions as they have been gradually worked out by us. If any should wish to verify our statements, and see the force of our reasoning, we advise them to visit the different localities in the order in which we describe them. For the processes begun at Newport seem to be carried to their completion in Vermont.

Perhaps the best place to visit the Rhode Island locality is at the well known Purgatory, two and a half miles east of Newport, and within the limits of Middletown. According to the paper of C. H. H., read before the Scientific Association in August, 1860, the belt of conglomerate commences a little south of Purgatory, is a mile wide, with interstratified belts of slates, and extends northeasterly probably as far as Sandy Point in Portsmouth, some five and a half miles. It shows several folds, is underlaid by a gritty schist, or sandstone, and itself underlies the coal measures. "It is a coarse conglomerate, composed of elongated and flattened pebbles, from the smallest size to bowlders nearly twelve feet long, cemented by a meager amount of talcose schist or sandstone," with numerous small disseminated crystals of magnetite. The pebbles are mostly a fine grained or compact quartz rock, which when partially decomposed appears like sandstone; not unfrequently the pebbles seem to pass into an imperfect mica schist, and show lamination. A few of them are gneiss, and probably granite, and occasionally hornblende rock. In their shortest diameter they rarely exceed a foot, while in length, one, two and three feet are very common, and a few may be seen from four to six, and one at least as long as twelve feet. The following facts as to the pebbles are of the most scientific interest:

1. They are elongated often very much in the direction of the strike. 2. They are flattened, but not so strikingly as they are elongated. 3. They are indented often deeply by one being pressed into another. 4. They are sometimes a good deal bent, sometimes

in two directions. 5. They are cut across by parallel joints or fissures, varying in distance from each other from one or two inches to many feet. The most distinct of these joints, which are a rod or two apart, are perpendicular to the horizon, and nearly at right angles to the strike, and make a clean cut from top to bottom of hills thirty or forty feet high.—Abrading agencies have often removed the rock on one side of these joints, or between two of them, so as to leave walls of pebbles smoothly cut in two; the whole appearing like a pile of wood that has been neatly sawed. Acres of such walls may be seen in the vicinity of Purgatory. Often the surface of the pebbles, thus cut through, is not only perfectly even but smooth, and seemingly polished. Yet the two parts of the pebbles thus cut off perfectly correspond, and one part has never been made to slip over the other. In some minor joints single pebbles are not entirely cut off, but are sometimes drawn out of their beds at one end when the rock is separated, and remain projecting above the general cleaved surface. These joints, also, do not always extend through the whole rock. We would be glad to introduce here many sketches of specimens illustrating these statements. But one or two must suffice. Fig. 6 will give some idea of an elongated pebble from Newport, which is 10 inches long and 3 inches across its broadest part.

Fig. 6.

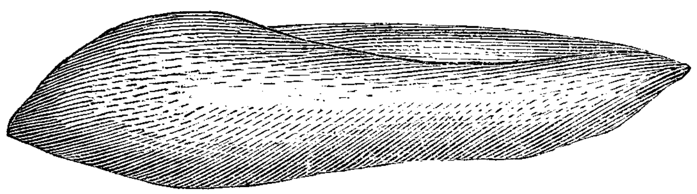
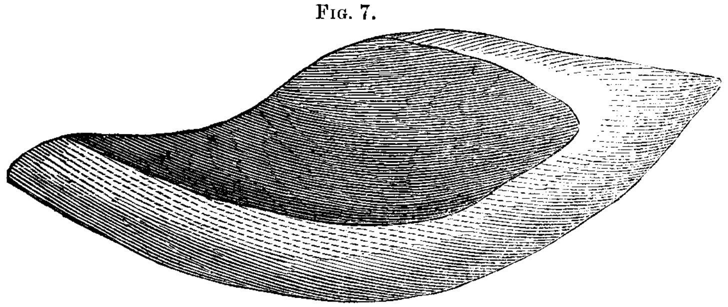


Fig. 7 shows a pebble 8 inches long with a deep indentation.

Fig. 7.



Perhaps I ought to add that sometimes the elongated pebbles partially or wholly lose their rounded form at the ends, begin to assume a foliated or schistose aspect, and are somewhat blended with the talcose or micaceous cement. This, however, is not generally though not unfrequently the case.

From these facts we could hardly avoid drawing the following conclusions:

1. This rock was once a conglomerate of the usual character, except in the great abundance of the pebbles, and it has subsequently experienced great metamorphosis, making the cement crystalline and schistose, and elongating and flattening the pebbles.

2. The pebbles must have been in a state more or less plastic when they were elongated, flattened and bent. If their shape has been thus altered, their plasticity must of course be admitted: for the attempt to change their present form would result only in fracture and comminution. The degree of plasticity, however, must have varied considerably; for some of them are scarcely flattened or elongated at all; and, as here stated, some are not cut off by the joints.

The neat and clean manner in which the pebbles have been generally severed by the joints, implies plasticity. For though occasionally we meet with one that has a somewhat uneven surface, as if mechanically broken, such cases are rare. Whatever may be our theory of the agency that has formed the joints, the conviction is forced upon every observer that the materials must have been in a soft state when they were produced.—There is no evidence that the opposite walls have slid upon one another at all, as the opposite parts of the pebbles coincide. It seems as if a huge saw or cleaver had done the work.

These proofs of plasticity apply essentially though less forcibly to the micaceous and talcose cement which has also been cut-across by the joints. Though generally in small quantity, it sometimes forms layers of considerable thickness, interstratified with the pebbles.

Some have imagined that the elongated, flattened, bent, and indented pebbles of this conglomerate may have been worn into their present shape, and brought into a parallel arrangement, by the mechanical attrition of waves and currents. We feel confident that extensive and careful examination of the localities, and of beaches where shingle is now being formed, will convince any one that they cannot have had such an origin. 1. We do not believe that any beach can be found with pebbles that have anything more than a slight resemblance to those at Newport. Those somewhat elongated may indeed be found, when they are derived from slate rocks. But nowhere does the attrition of pebbles against one another produce deep indentations and leave the one neatly fitting into the other, nay, one bent partially around the other, as is the case at Newport. If these phenomena were produced by original attrition, how strange that they should have such an extraordinary development in Rhode Island, while it is not marked enough in any other conglomerate in our country, so far as I know, — save in Vermont,— to have arrested the attention of geologists. 2. The remarkable joints in this conglomerate prove that the pebbles have been in a plastic state, and since the strata have been much folded and consequently subjected to strong lateral pressure, how could the pebbles have escaped compression and modification of form? A mass of the conglomerate, when broken open along the line of strike, a good deal resembles a pile of tobacco, which has been rolled into lumps and then subjected to strong pressure, so that the junks are distorted and made to conform to all the irregularities around them.

3. The force by which the pebbles were flattened and indented must have operated laterally, as would be done by the plication of the strata, folds in which are frequent. And if there was a great superincumbent pressure, and less in the direction of the strike, the same lateral force might have elongated the pebbles. But perhaps there may have been, also, a horizontal curvature in the strata to aid in the work, as we shall explain when we come to describe the Vermont localities. It may not, however, be easy to show how this compressing force has operated where rocks have been so folded and disturbed as around Newport, for the conglomerate is in juxtaposition with granite, which has exerted a powerful metamorphic influence on other strata there; but if we can show the results of the agency, our main object will be accomplished.

4. The phenomena of the joints in this rock conduct us most naturally to some polar force as the chief agent in their production, such as heat or galvanism. Mere shrinkage could not have separated the pebbles so smoothly; much less could a strain from beneath have thus fractured them, for sometimes the joints are not more than two or three inches apart; and if we suppose one of them to have been the result of fracture, yet how is the other to be obtained in that manner? A simple inspection of the rock in place will

satisfy any one that no mechanical agency is sufficient to explain these phenomena. We have been driven to the supposition of some polarizing force acting upon soft materials. If, as Sir John Herschell supposes, cleavage may have resulted from a sort of crystallization in plastic materials, why may not joints come into the same category? Why should the conclusions drawn from the experiments of Mr. Fox upon the lamination of plastic clay by galvanism, be limited to cleavage?

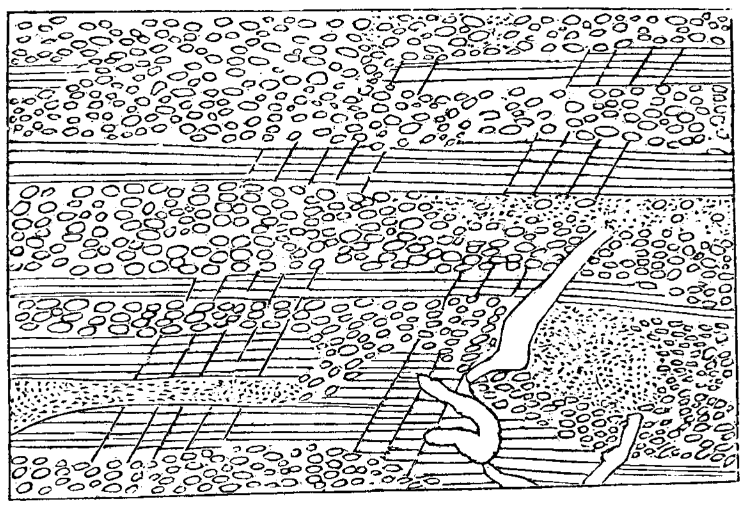
5. The Newport conglomerate is probably only a modified variety of that extensive deposit of highly silicious pudding stone found so abundantly between Boston and Rhode Island. Both have the same geological position we believe, and were the Roxbury conglomerate to be brought into a plastic state and the pebbles elongated and flattened by pressure, we think the Newport conglomerate would be the result.

Thus far we think we are legitimately conducted by the Rhode Island rock. We are carried farther by the Vermont conglomerate, which we now proceed to describe. We select two localities, although doubtless many others might be found, equally instructive. The rock occurs on both faces of the Green Mountains, and we can hardly doubt that it once formed a fold over the mountain, which denudation has swept away.

We have found this rock in connection with quartz rock, mica and talc schists and gneiss; sometimes merely in juxtaposition, as in the case of the quartz rock, but sometimes interstratified. The conglomerates at the different localities may not be identical as to geological age; yet we incline rather to the opinion that quartz rock, micaceous and talcose schist and gneiss, may be varieties of the same original rock, which metamorphism has sometimes converted into one, and sometimes into others, of the series. Quartz rock may be the residuum of certain silicates; the schists and gneiss are those silicates modified. Any of these rocks we think might be formed out of the conglomerate under consideration, as we shall now endeavor to show. If so, we might perhaps find it in connection with them all, without implying a difference of age.

In the northeast part of Wallingford, on the western slope of the Green Mountains, on the hill north of David Hager's, is an interesting exhibition of the conglomerate.—

East. FIG. 8.

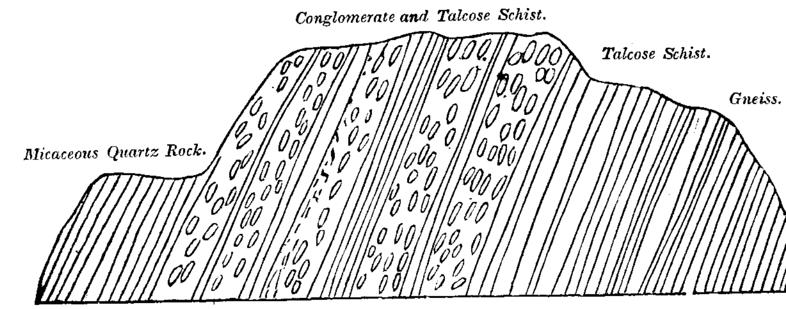


Surface of Wallingford Conglomerate.

Numerous bowlders are scattered over the field, which are instructive; but the embossed ledge half a mile north of Hager's is the most so. It has been rounded and smoothed by the drift agency, so as to show the pebbles and their alternation with the schists very distinctly, as the foregoing sketch of a portion of the ledge, taken by one of our number (A. D. H.), will evince. It will be seen that the schist, often containing small pebbles or coarse grains of sand, is interstratified somewhat irregularly with the pebbles, just as we often see in alluvial deposits and in sandstones that have not been metamorphosed. The drift striæ are quite distinct upon it, running southeasterly, as shown on the sketch.

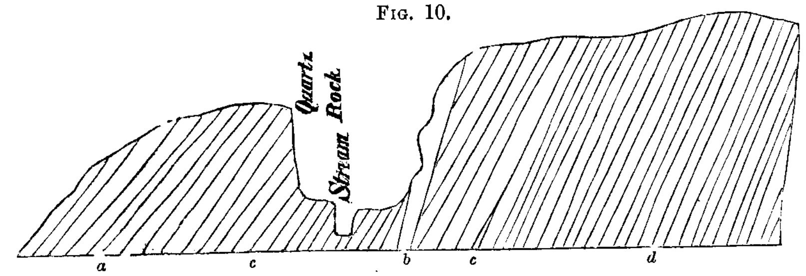
The strike of these strata is about N. E. and S. W., and the dip 70° W., but it sometimes rises to 90° in the vicinity. To show its position in respect to a micaceous quartz rock approaching micaceous schist on the upper side, and to the Green Mountain gneiss below it, we give the sketch beneath. These rocks constitute a single massive ledge with very few distinct strata seams, and they seem as if only varieties of the same rock.

FIG. 9.



To show that the gneiss sometimes lies above the quartz and the schist, we give the following section (Fig. 10), only a few rods long, taken at an easily accessible locality on the east side of the mountain, where, as we shall shortly see, the same rocks occur in juxtaposition, on the road from Ludlow to Mount Holly; and near the line between the two towns, a small stream has cut a gorge, 40 or 50 feet deep, through a ledge of quartz rock. On the west side a trap dike occupies a considerable part of the face of the rock, though more or less worn away. Talcose schist succeeds the quartz rock on the west side, dipping beneath it at a high angle. But on the east side, and lying upon the quartz at a less dip, is distinct gneiss, with more of feldspar than is usual in the Green Mountain gneiss. The section below will give an idea of these facts.

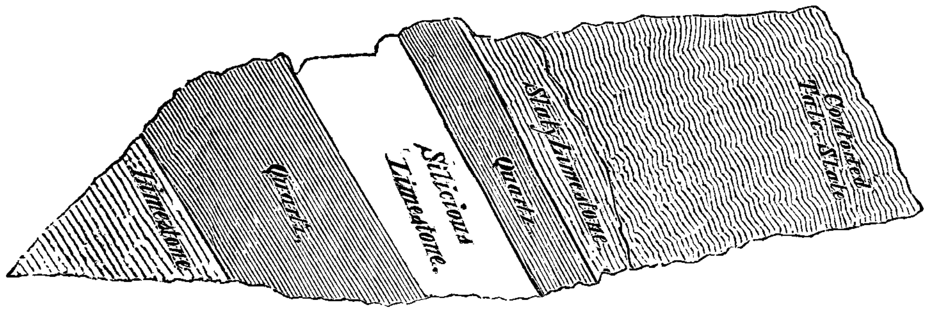
FIG. 10.



a, gneiss; *b*, trap dike; *c c*, quartz rock; *d*, talcose schists.

A. D. H. furnishes the following sketch (Fig. 11), showing the position of the talcose schist and beds of quartz and limestone east of the ponds in Plymouth. These strata lie above the conglomerate to be shortly described, on the west side of those ponds in that town. The facts here shown have a bearing upon our conclusions.

Fig. 11.

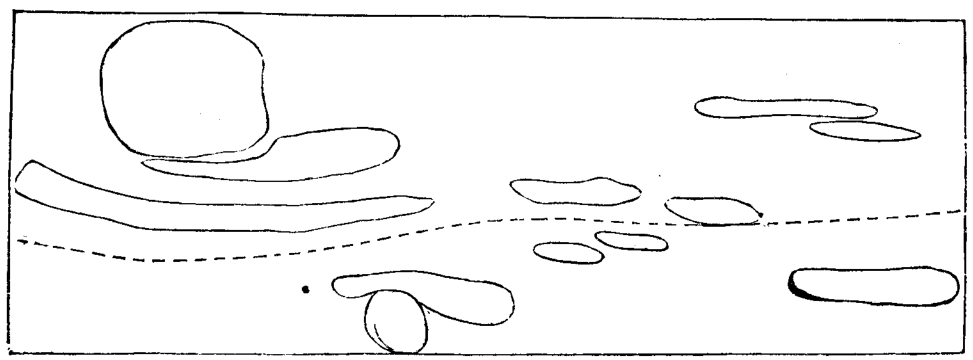


Section east of Plymouth Ponds. Dip 55°

More than nine-tenths of the pebbles in the Wallingford conglomerate are gray, somewhat granular, but often more or less hyaline quartz. White feldspar nodules are not uncommon. Quartz is sometimes disseminated through the feldspar, so as to form a sort of graphic granite. A few pebbles of distinct gneiss have been noticed. But it is not unusual for the micaceous cement to exhibit folia of feldspar, becoming in fact veritable gneiss; and perhaps the gneiss pebbles may all have thus originated. The most striking pebbles of feldspar, however, are seen in a finer variety of the rock, destitute of quartz pebbles, but showing small, white, rounded masses of feldspar, rarely over half an inch in diameter. We are of opinion that all the feldspar pebbles, as well as the narrow strips of gneiss, are the result of metamorphism; that is, the pebbles were changed in mineral constitution, and the gneiss actually formed by metamorphic processes. But we shall recur to this subject again in the sequel.

Most of the pebbles are somewhat elongated in the direction of the strike on a horizontal surface, so as to give them an egg-shaped appearance. But where joints or other fissures have exposed the edges of the strata at right angles to the strike, the elongation, flattening and bending of the pebbles are much more striking, as the following outlines (Fig. 12), made by C. H. H., will show. Yet even here a few pebbles seem not to have been modified at all in form, two of which are shown on the drawing. They seem not to have been plastic, as the others were.

Fig. 12.



Elongated Pebbles, Wallingford.

Single pebbles sometimes show striking curvatures, as in Fig. 13, where *a* represents a pebble ten inches long, and a little more than one inch wide; *b* shows a smaller one less curved, $5\frac{1}{2}$ inches long and half an inch wide.

Fig. 13.

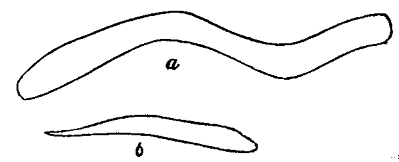


Fig. 14 was copied from No. $\frac{5}{191}$ of the State Cabinet from Wallingford, one-fifth the natural size. The bowlders of this conglomerate scattered over the fields, often contain interesting exhibitions. Fig. 15 was copied from one five feet long. It shows a band of pebbles in the lower part, interstratified with schist, and in the upper part a crooked vein of white quartz. The lower part is what we not unfrequently meet in sandstone. The upper part occurs almost exclusively in the highly metamorphic schists.

Fig. 14.

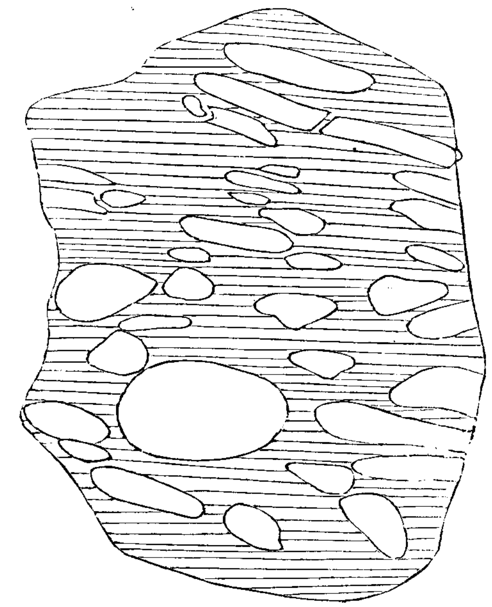
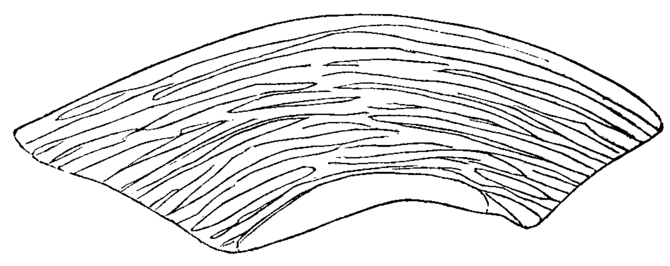
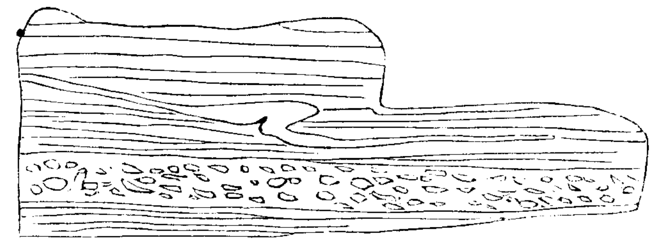


Fig. 16.



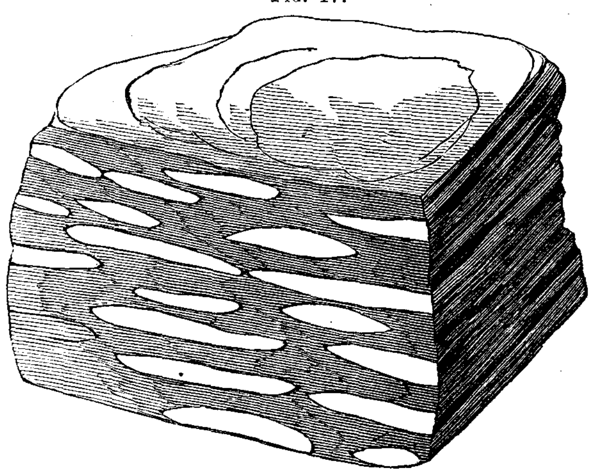
A still more interesting case is shown in another bowlder a few feet long, represented imperfectly in Fig. 16. Here the folia of the schists are bent considerably. On the inner side is a quartz pebble of considerable size, which is elongated and bent somewhat; but as we go outwardly the pebbles are so much flattened that they can hardly be distinguished from the quartzose folia of the rock. At the time this sketch was taken we did not fully realize the important bearings it might have upon theory, therefore we fear that it is not as minutely accurate as to every pebble as could be desired. Still the general facts above named are quite manifest, and these are all that is important.

Fig. 15.



The preceding facts would justify some inferences additional to those drawn from the Newport rock. But we will first describe another locality on the east side of the Green Mountains, where the metamorphic processes, begun at Newport and carried still farther at Wallingford, are completed in the most satisfactory manner. It is at Plymouth, along the west shore of Plymouth Ponds, most fully developed perhaps, just where the ponds are separated by a mass of detritus, which was most probably the Moraine of an ancient glacier, as will be described in another place. The schist here, which is decidedly for the most part talcose schist, and not far from some of the gold diggings, has an easterly dip from 50° to 60°, in a direction a few degrees east of north. As the ledges crowd closely upon the road, a fine opportunity is presented of seeing the quartz pebbles that have not been much flattened on the exposed surfaces, having the aspect of a most decided conglomerate. Yet if joints cross the rock, or if it be broken across in the direction of the strike, the pebbles will, for the most part, appear so flattened that they become almost lenticular, or even folia. And if a fracture be made, or a joint occur, in a perpendicular direction, that is in the direction of the dip, the pebbles almost wholly disappear, or rather seem converted into the quartz folia of talcose schist. Both these facts are shown on Fig. 17, which was copied from one of the specimens obtained at this locality. Looking at one of these edges, we should have no hesitation in referring the rock to a highly quartzose variety of talcose schist. But looking at the other edge, we should have no doubt that the quartz folia are merely flattened and elongated pebbles. So strange and unexpected a fact leads the geologist to suspect that he may be deceived: but hundreds of specimens force him to the conclusion that he is not mistaken.

Fig. 17.



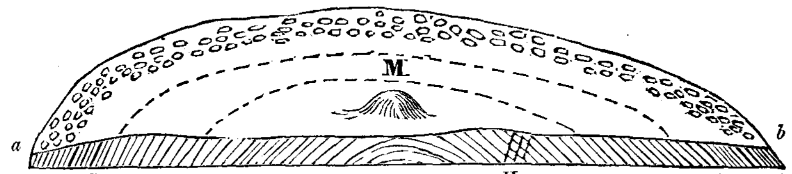
The quartz in this rock, both in Wallingford and Plymouth, is generally white or a light gray, and though sometimes granular, it approaches much nearer the hyaline variety in most instances. It seems to be quite pure silex rather than a silicate. In a few instances we find pebbles of granite, which are also flattened.

The suggestion has been made that what I regard as pebbles may be concretions. But the following facts seem to me to show this position to be untenable. 1. We have no other examples of concretions formed of hyaline or granular quartz. 2. Silicious concretions, such as chalcedony, formed by gelatinous silex, are banded; but these nodules show no concentric structure. 3. Concretions are never, as these nodules are, drawn out into the folia of schists. 4. Some of them are composed of granite, gneiss, &c., which are certainly never concretions. 5. If these nodules are concretions, so are the pebbles of quartz and granite found loose in modified drift; or rather, no line of distinction can be drawn between the concretions and the pebbles.

The thickness of the rock where the pebbles are manifest, is many hundred feet; indeed it may be much more, as I have not fully explored it. And if, as we suppose, the strata already described in connection with the conglomerate, are only that rock in an advanced state of metamorphism, the original thickness must have been very great. We have ascertained also that the layers with pebbles extend as far south as Ludlow, though nearly converted there into mica schist; nor can we doubt but it may be traced much farther north and south, perhaps even the whole length of the Green Mountains. At any rate its occurrence on the opposite sides of that mountain—at Wallingford and Plymouth—at points not much different from east and west of each other, leads to some interesting suggestions and conclusions. The distance between these points is about ten and a half miles.

Myself and son, aided by the senior class of 1861 in Amherst College, have recently (October 1860) traversed this line mostly on foot, and obtained, as the result, the section below (Fig. 18). The base of the section is the sea level, and the heights are laid off from the same scale as the horizontal distance. This makes the Green Mountains (1390 feet above the ocean at Mount Holly) appear of very diminutive height. But it is a true representation, excepting that the summit is a little too high in order to give the lines distinctness. On both the flanks of the mountain the dips are quite distinct (they were measured along the railroad from Ludlow to the summit as well as from the Plymouth Ponds, and the mean taken), but in the central parts they are a good deal irregular. It will be seen that all the central part of the mountain is gneiss of the peculiar kind known as the Green Mountain gneiss. Above this lies what has been called talcose schist, with which limestone is interstratified; and on the east side several beds of dark gray hyaline quartz, only a few feet thick. One of the beds, however, is snow white. The upper part of the schist is the conglomerate already described, of a character so marked as not to be mistaken. At the west end we found several beds of limestone, but none of quartz. Beyond the conglomerate, however, and probably lying conformably upon it, is an enormous development of granular quartz, which seems to have no counterpart on the east side of the mountain.

Fig. 18.



In this section *a b* shows the present surface, *a* being Wallingford, and *b* Plymouth.—From A to B we have the talcose conglomerate; from B to C mainly gneiss, with some schist, and at least three beds of limestone; from C to D gneiss, with several trap dikes at H, the summit level of the railroad; from D to E gneiss, with talcose schist, and at least two beds of limestone and several thin beds of quartz; from E to F talcose conglomerate. This last rock, so distinct and peculiar, forms a good starting point for our reasoning. I think no geologist will doubt that it once mantled over the mountains with the subjacent strata, as represented in the above section. True we have not found all the subordinate beds of limestone and quartz to correspond on the two sides of the mountain. But there is a general correspondence. The beds of limestone, especially, may have originally extended over the arch of the mountains, although it is not common to find limestone beds as thin as these, with so great a lateral extension. And as to the beds of quartz, if this be in nearly all cases a residuary rock, produced in the wet way, all we can say is, that circumstances may have been more favorable for its production on the east than on the west side of the arch of the mountain.

Taking this section as a fair representation of the Green Mountains, several important inferences follow. 1. It shows the gneiss of the Green Mountains to form a great anticlinal fold — not a synclinal fold, as some have supposed. 2. This gneiss underlies the talcose schist, the limestone, the quartz rock, and the conglomerate. 3. All these latter rocks probably once mantled over the gneiss, though they have mostly disappeared from the eastern side, except the talcose schist. 4. We get an approximate idea of the amount of erosion from this part of the Green Mountains. We have flattened down the curve described by the strata originally, more than perhaps we ought to do; yet it seems almost twice as high as Mansfield Mountain which is shown on the section at M, and is the highest point in the chain. The erosion at Mt. Holly cannot have been less than 8000 feet, which is nearly six times as great as the present height of the mountain at the summit level of the railroad. 5. We see here how the schists and gneiss may be formed out of conglomerate. This is perhaps the most important inference, and therefore it will be dwelt upon more fully in the sequel.

We proceed now to draw some inferences from the facts detailed respecting the Vermont conglomerates, additional to those already given. The Vermont localities teach the same lessons as those in Rhode Island; but we think they develop other conclusions.

1. They show, we think, that the elongating and flattening force in Vermont must have operated most energetically in the direction of the dip, whereas in Rhode Island it was most powerful in the direction of the strike. In the latter case it was as if two men had taken hold of the ends of a plastic mass and pulled it out horizontally: but in Vermont it is as if one had stood at the top of a steep hill and the other at the bottom. This is evident from the fact that when we look at the edges of the rock laid bare along the line of dip, we see little more than the flattened edges of the pebbles in the form of folia; but if laid bare along the line of strike, we see the flattened and even lenticular ends of the pebbles as shown on Fig. 17 already given. The fact, however, that the pebbles are lenticular on the basset edges of the strata, show that the whole force was not exerted in the direction of the dip. They were a good deal flattened horizontally, but more so vertically.

2. We think we get a glimpse in Vermont of the mode in which the force acted to elongate and flatten the pebbles. We refer to the bowlder shown on Fig. 16, where it is obvious that the bending of the rock, if it was plastic, would produce that effect, because the outer portions must be extended over wider and wider spaces. Hence, as in the figure, a pebble on the interior part might be only moderately extended, while the outer ones were stretched almost into mere laminæ.

Apply now this principle to Fig. 18 which shows the manner in which, as we suppose, the strata were folded over the top of the Green Mountains. The effect would be to stretch them out more in the direction of the curve, or dip, than at right angles to it, although the strain would spread them in that direction also, to some extent; and it may be that the irregularities that must have accompanied such great movements as the folding up of a mountain chain, would make the horizontal elongation in some places the greatest.

We do not assert that this explication of the phenomena is certainly the true one; but only that it shows one mode in which the process might have been performed. Whether any horizontal flexure can be found in the Rhode Island rock, to explain the elongation there, we are unable to say, because the theory was not in our minds when we examined those rocks.

3. The facts detailed disclose to us some of the modes in which the folia of the schists and of gneiss may have been produced. The first mode is by chemical agencies. Out of the cement of conglomerate, these agencies have formed mica, talc and feldspar, whose parallel arrangement was probably the result, mainly, of pressure. We doubted for a time whether we could justly include gneiss among the rocks that may have originated from conglomerate; for we have not found as yet, decided examples of pebbles in this rock. Yet so intimately connected with the conglomerate schists is the Green Mountain gneiss, as the preceding details show,—so little in fact does it differ from the schists, that we cannot doubt that both originated from the same original formation. But the conglomerate at Wallingford affords still stronger evidence, and shows us the modes in which the gneiss was produced from the conglomerate. Some of the elongated pebbles there are gneiss. But we doubt whether they were originally so. For quite often the cement is changed to gneiss. To effect this change it was only necessary that feldspar should be interpolated between the folia of mica or talc. And no one who has seen the specimens will imagine that it could have been introduced mechanically—by deposition for example. The wet way, or crystallization from solution, is the only other probable mode. Most likely gneiss generally has been formed by such an interpolation of feldspar into the schists, and this may be the reason why we seldom, perhaps never, see pebbles in that rock. We do not yet despair, however, of finding pebbles in gneiss, now that we have learnt how to look for them. Indeed some varieties of it contain nodular elongated masses of feldspar, interfoliated perhaps with mica, which may have been pebbles originally, which have been changed chemically and elongated mechanically.

The second agency by which conglomerate has been converted into schists, is mechanical. By some force the pebbles have been flattened and elongated till they have become the quartzose folia of the schists. It is not probably possible for us to convey a very clear and complete idea of the evidence of this position. Would that our readers could, as we have done, visit the localities again and again, and become familiar with the striking specimens there, by repeated and careful examination. From our own experience, it would not surprise us if the conversion of the pebbles of the conglomerates into the folia of schists should be pronounced preposterous by able geologists. So the idea seemed to us at first, when the facts forced it upon our attention. But as the facts compelled us to give up our scepticism, so we think they will do with any candid mind. For if we look at almost any specimen of the talcose conglomerate schist on the edge corresponding to the dip (Fig. 17), we should see nothing but alternating folia of quartz and talc or mica, and pronounce it a good example of the rock which we have called, and which is generally called, talcose schist. But a fracture at right angles reveals the flattened pebbles (Fig. 17), and shows us that their edges are what we have regarded as folia. Let the process of flattening be carried a little farther, and no evidence will remain that they ever were pebbles. Who knows how extensively the process may have been thus carried through in the schists and gneiss of the Green Mountains, and how large a part of them may once have been conglomerates? Our aim, however, is not to show the extent of the metamorphosis, but only to prove its occurrence on a large scale.

4. A fourth conclusion forced upon us by the facts is, that the chemical constitution of the pebbles has generally been altered in the process of metamorphism, without obliterating their original character as mechanically formed.

As has been repeatedly stated, most of the pebbles in the Vermont rocks are quite pure quartz, having often more or less of a vitreous aspect. In fact it is nearly pure silex, and it is that form of silex which is absolutely insoluble in anything but hydrofluoric acid; nor can we suppose the presence of any heat high enough to melt it, without completely destroying the forms of the pebbles. Yet the evidence that they have been in a plastic state, so as to be moulded by pressure, is too decided to be resisted. How then have they been softened?

Let us recur to the conglomerate at Newport. Most of the pebbles there are not pure quartz, but rather silicates; that is, silex united with bases, such as alumina, magnesia, lime and iron. Now the silicates are soluble by water containing alkalies; and such quartz as the Vermont pebbles is the residuum of their decomposition; that is, the bases are abstracted to form other compounds, and the quartz is left. This is the most probable theory of the origin of quartz rock generally. Even if we suppose it produced from sandstone, we know of no other way in which it could have been formed, for nearly all the sandstones are silicates.

But suppose the silicates in the form of pebbles to be permeated by water containing alkalies—could their bases be abstracted without entirely destroying the form of the pebbles? We do not see why this could not be done, if kept in such a state by the water that they could obey the laws of chemical affinity and form new compounds, and leave the quartz behind. The chief effect upon the pebble would be to reduce its bulk, though we do find sometimes the cement so strongly adhering to the pebble that it can hardly be separated so as to leave a smooth surface. The bases we think would be mostly used in forming the micaceous or talcose cement, and if there was a good deal of pressure upon the whole rock, as we may reasonably suppose—if the pebbles did shrink some, the cement would increase and the whole would be kept compacted together.

To sustain the position that the mineral constitution of pebbles in conglomerates is sometimes entirely changed without destroying their character as pebbles, we would refer to another kind of conglomerate, which we have found along the eastern border of Vermont and farther south in Massachusetts. This rock, so far as we know, has never been described in treatises on geology: but we know of four localities along the west side of the Connecticut River, and its character and origin are quite obvious. We reserve the minuter details to another part of our Report, and mention here only the facts that bear specially upon the point under consideration.

We define this rock as a conglomerate with a cement of syenite or granite, or as a syenite or granite with pebbles in it, sometimes thickly and sometimes sparsely disseminated. We have found it in Whately, Massachusetts, on Ascutney, and in Barnet and Granby, Vermont. On the southwest point of Little Ascutney we find a conglomerate, or perhaps a breccia, which is made up of fragments of silex and some mica, probably a sandstone, with nearly pure quartz. On one side of this mass it passes, without an intervening seam, into a porphyry, and this into granite, all forming one undivided ledge, so that the conclusion is forced upon us that the granite and porphyry have been formed out of the conglomerate. Most of the rock on Ascutney takes hornblende into its composition, and thus becomes syenite, and this abounds in black rounded masses, which are for the most part crystalline hornblende with some feldspar, and which are probably pebbles transmuted. At Granby the pebbles, manifestly rounded, are either mica schist

or white almost hyaline quartz, just such as form the pebbles in the conglomerates at Wallingford and Plymouth, and the base is a fine grained syenite, passing sometimes almost into mica schist. A pebble of hornblende schist is also sometimes seen.

In bowlders of this conglomerate found in Northampton, Mass., and probably derived from Whately, the most abundant pebbles are those of the brown sandstone, considerably metamorphosed and flattened. Those of hornblende schist are common. Sometimes they are merely crystalline hornblende, not foliated generally, however, but mixed with some feldspar, and they may become syenite, and are frequently porphyritic by distinct crystals of feldspar. The cement is syenite, often more hornblendic than usual.

When the pebbles are highly crystallized they become so incorporated with the matrix that it is difficult to separate them with a smooth surface, and if we are not mistaken they pass insensibly into those rounded nodules, chiefly hornblendic, so common in syenite, especially that of Ascutney. We think those are produced from the metamorphosis of pebbles, which have become crystalline since they were formed into conglomerate. We find them as we think in all stages of the metamorphosis.

These facts certainly give great plausibility to the view which supposes granite and syenite to be often the result of the metamorphosis of stratified rocks, as we shall more fully explain in another place. But they afford a presumption, also, in favor of the position that pebbles, which have been plastic for ages in the rocks, may have greatly changed their mineral constitution without essentially altering their external form. This might certainly be thoroughly done if those pebbles were permeated by water containing in solution powerful chemical agents. Some of the ingredients might thus be abstracted from the pebbles and new ones supplied, if needed to form the new compounds.

In all the cases of pebbles in unstratified rocks described above, syenite has formed the matrix. But at the meeting of the American Scientific Association at Springfield, Prof. Hubbard, of Dartmouth College, exhibited a specimen of pure white granite from Warren, New Hampshire, in which there lay imbedded a rounded bowlder of hornblende rock, more than a foot in diameter, and easily separable from the granite. We had no doubt but that it was mechanically rounded, nor much doubt but that its mineral character had been changed since it was enveloped in granite. Hornblende bowlders in the drift are among the most unfrequent of all rocks, because hornblende schist is very limited. But in the older metamorphic conglomerates such nodules are the most common of all, and this fact furnishes a presumption of their metamorphic origin.

The facts which we have detailed respecting the occasional presence of feldspar pebbles in the Vermont conglomerates, and especially the conversion of the cement occasionally into gneiss, are most probably examples of a change of mineral character during metamorphosis. It seems hardly possible to account for a cement of crystalline mica or talc in any other way. But when we find feldspar interpolated between the folia, any other than a chemical origin is superlatively absurd. We cannot, therefore, but regard feldspar, in perhaps all cases in the crystalline rocks, as the result of metamorphism. Silicates probably furnished the ingredients, which being abstracted by hot water, left the excess of silica in the form of quartz, and formed the feldspar and mica to fill up the interstices.—The feldspar which has converted the cement into gneiss could have had no other origin, and this fact, in connection with all the rest which have been adduced, affords a presumption that feldspar in nearly all the crystalline rocks, stratified and unstratified, is a product of metamorphism.

We will add a few words as to other localities of conglomerates with flattened pebbles. It is only so recently that the full *denouement* of the subject has opened upon us, that we have not had time to visit others. But we happen to have specimens from Bernardston, Mass., in which the elongation and flattening are decided, in a conglomerate micaceous schist connected with clay slate and quartz rock. The same is true to some extent in a like rock from Bellingham, Mass. Still more decided is it in bowlders of the conglomerate syenite described above from Northampton; as it is also in the same variety of rock on Little Ascutney. In fact we predict that this phenomenon will be found present in very many of the thoroughly metamorphic conglomerates, although not noticed by observers because their attention was not called to it.

Less than a mile north of the conglomerate locality in Plymouth, Vt., on the east side of the Pond, and nearly on the strike of the conglomerate, occurs a remarkable variety of marble in an unstratified bed several rods wide. It consists of a ground of dark limestone, through which are disseminated numerous elongated masses from half an inch to six inches long, and from a quarter of an inch to an inch wide, of white semi-crystalline carbonate of lime. Their longer axes lie as nearly parallel to one another as those of the quartzose conglomerate. What their origin was I have scarcely ventured to conjecture. One naturally inquires, however, whether they may not be elongated organic remains, such as corals. At any rate the inquiry may be worthy of consideration whether they are not something elongated by the same force that has acted on the not far distant conglomerate. This idea did not occur to me when in the vicinity, and therefore I did not go to determine the point. If there be any foundation for this suggestion, we should expect that the longer axes of these nodules would correspond more nearly with the dip than with the strike. I have not the slightest recollection whether it is so.

The chief interest in the facts and conclusions in the preceding discussions, lies in the light they cast upon metamorphism. We had indeed felt that there was a good deal of probability in the general doctrines of metamorphism advanced by able men. But never before have we had the various steps of the process brought directly under our eyes, and so distinctly as to confound our scepticism and challenge our belief. Instead of any prejudices in favor of the conclusions to which we have been brought, our prepossessions have been the other way. But we could not resist evidence so clear, and we find that our new views greatly eclaircize the subject of metamorphism. It seems to us difficult to conceive how geologists can avoid the conclusions we have presented, if they will visit and study the localities we have pointed out. And yet we know very well how different impressions are made by the same facts upon different minds, equally able and apparently equally impartial, and therefore we expect the views we have presented will be controverted. But time will bring out and establish the truth.

March 20th, 1861. A brief and important summary of the preceding facts and arguments having been presented by me last autumn before the Boston Society of Natural History, Dr. Charles T. Jackson expressed his dissent from my views as to the manner in which the pebbles had been flattened and distorted, and his conviction that they had either been worn into those shapes by water, previous to aggregation, or that some of them were concretions. At a subsequent meeting Prof. Wm. B. Rogers expressed similar views, which appear in the published proceedings of the Society. I do not understand these distinguished geologists to have made up their minds very decidedly on the subject, especially as they have not visited the Vermont localities. But objections suggested by gentlemen of such large geological experience deserve serious consideration.

I have already stated my objections to the theory which they adopt as to the forms of the pebbles. Prof. Rogers suggests as an objection to my views, that the pressure which I suppose to have flattened and distorted the pebbles, has not produced cleavage. But this conglomerate is not a rock in which cleavage is ever found. It is a foliated or schistose rock. It has joints in it, such as prove very clearly that it was once in a state more or less plastic; but these (the most perfect ones especially) cross the folia nearly at right angles, and could never have been produced by pressure. It is a fact, however, that some of the larger pebbles, particularly at their extremities, do show the commencement of a schistose structure—probably the result of pressure. Yet the facts do not require us to suppose the pressure on this rock to have been of the most powerful kind. In some cases, indeed, as at Plymouth, the pebbles are compressed into folia; but in general they are only moderately flattened, and sometimes not at all. If only moderately plastic, such effects could not have required a very enormous force.

Another objection is, that the compression has not distorted the fossil Lingulæ, found in the pebbles on Taunton river and at Newport. But I am not aware that the pebbles in the conglomerate of Taunton river have been compressed and elongated; nor have they been, in but a part of that around Newport. Whether they have been in the particular pebbles containing the fossils, I am unable to say. A third objection rests upon the fact that some of the pebbles have scarcely been flattened at all, and their longer axes cross the foliation; though I do not myself recollect to have seen any whose position was much awry. But some of them, on account of their composition, may have been scarcely at all plastic, or had such a position that the pressure affected them but slightly. We certainly ought to expect such cases.

I have been led of late to a re-perusal of the able papers that have appeared for several years past in the English Journals, on cleavage, compressed and distorted fossils, and particles of slate, by Sharpe, Sorby, Tyndall, Scrope, Scheerer, and Haughton. The result is, a conviction that the facts which I have given respecting the conglomerates are only another phase of the phenomena described by these eminent geologists. If the facts they adduce prove the elongation and expansion of slate, limestone, and fossils, as is generally conceded, although proved mainly by the microscope, why should we think it strange that the like effects may have been produced upon conglomerates, so as to show themselves on a large scale, and to unaided vision? The manner in which the veteran geologist Scrope supposes gneiss and mica schist may have been formed out of granite (which he has illustrated by figures, Phil. Magazine, Vol. LI. p. 196), whatever we may think of the hypothesis, corresponds very nearly with some of my suppositions, or rather *facts*, as to the conversion of conglomerates into the schist. And the ideas of most of these writers as to the former plastic condition of most of the rocks, correspond with those which I have expressed. If I am wrong then, I have the consolation of being in good company.

Prof. Tyndall, in his recent work on the Alpine Glaciers, has referred to an interesting specimen in London, analogous to the conglomerates of Rhode Island and Vermont:

"In the Museum of the Government School of Mines," he says, "we have a collection of quartz stones, placed there by Mr. Salter, and which have been subjected to enormous pressure in the neighborhood of a fault. These rigid pebbles have, in some cases, been squeezed against each other so as to produce a mutual flattening and indentation. Some of them have yielded along planes passing through them, as if one half had slidden over the other; but the re-attachment is very strong. Some of the larger stones, moreover, which have endured pressure at a particular point, are fissured radially around this point. In short the whole collection is a most instructive example of the manner and extent to which one of the most rigid substances in nature can yield on the application of a sufficient force." (Glaciers of the Alps, p. 404, Am. ed.)

Though these specimens are not so definitely described as we could wish, we presume they are conglomerates with flattened quartz pebbles, like those in Rhode Island and Vermont. Our objections to Prof. Tyndall's hypothesis, which imputes the effect wholly to the mechanical compression of solid quartz, are as follows:

1. The compression of pure quartz pebbles, such as some of those in Rhode Island, and most of those in Vermont, would break and crush them; nor have we any reason to suppose that the fragments could be re-constructed so as to form hyaline masses without fissures. There is no fluid, as in ice, to produce regelation; nor could the particles be brought near enough for molecular attraction without being crushed into the finest powder, by such a pressure as the facts show not to have been exerted upon the conglomerates.

2. The compressing force has not been great enough to destroy, except partially, the form of the pebbles. It has not crushed, but only moulded them, except that now and then one has been fractured. If it had been powerful enough to compress and distort solid quartz and to re-unite its particles, it must have destroyed all marks of a mechanical origin in the pebbles.

3. There is evidence, as we have tried to show in the preceding discussion, that many of the pebbles, especially in the Vermont rocks, have undergone a chemical change; that certain silicates have been abstracted from them, leaving the excess of silica in the form of quartz. This of course would require such a degree of plasticity as to enable water to permeate the mass. We now add a few other proofs of plasticity.

6. The superinduced structures in the crystalline slates and schists shows that they must have been in a semi-fluid state when these were made. We refer to cleavage, foliation, and joints. Whatever theory we adopt as to their mode of formation, a yielding state of the ingredients was essential; whether we suppose, with Sir John Herschell, that cleavage is a sort of crystallization in plastic materials; or, as Sharpe and Sorby maintain, it has resulted from compression and extension; or, as to foliation, if as Daniel Forbes supposes, it has resulted from chemical action; or, as to joints, if we regard them as due solely to shrinkage and fracture. In all these cases, however, of cleavage, foliation and joints, we must, with Professor Sedgwick, suppose polarizing forces (e. g. heat or galvanism) to have been concerned, and these require the molecular movement among the particles which only plasticity can give. We know that joints are sometimes found in rocks that have not been much softened, and of course chiefly by mechanical agencies: but we do not believe that such as occur in the quarztose conglomerates of Rhode Island and Vermont could have been formed, such as they are, if the whole mass had not been plastic. But here is not the place to go into details on such a point. We hope to find time to recur to it again after we have described the unstratified rocks.

7. The insensible passage of schistose into unstratified rocks (gneiss for instance into granite) affords a presumption that the former have been in a semi-plastic state. For all admit the fluidity of granite, either simply igneous or aqueo-igneous. But if we can hardly tell often where the one ends and the other begins, it is fair to conclude that the unstratified have resulted from the more thorough and complete operation of the same agency that produced the stratified crystalline group. This argument, however, would only show that the schistose rocks have been plastic, but gives us no information as to their previous consolidation.

We should not have spent so much time on this subject, did it not seem to have a most important bearing on the whole subject of metamorphism. Admit the schists subsequent to their consolidation to have been in a plastic state, by the agency of hot water, steam, and other re-agents, and the whole subject of metamorphism is easily explained. But deny this, and the phenomena seem inexplicable.

We resume now a detail of the effects of metamorphism. Several of these, however, have been touched upon in the preceding argument, and will need but little farther notice. The next one to be noticed in particular, has been brought out somewhat fully in the preceding argument, but it needs to be applied in other cases.

2. *A second effect of metamorphism is the abstraction of one or more of the ingredients of rocks and simple minerals by chemical agents.*

If silicious limestone, for instance, should be permeated by water containing some ingredients that would abstract the lime, a porous quartz rock would remain; or if in a plastic state and under pressure, it would become compact quartz, henceforth the most unchangeable of rocks. We incline to the opinion that this was in fact the mode in which very much of the larger deposits of quartz rock were produced.

If one or more proportions of oxygen were abstracted from peroxide of iron, or manganese, quite different ores would result. In this way have many of the simple minerals and many of the rocks been essentially changed.

3. *Similar results, only more complicated, would result from the introduction into the rocks of new ingredients, held in solution by the water diffused through the plastic materials.* Hence mineralogists reckon a large number of what they call pseudomorphs; that is, minerals which have the crystalline form of other minerals, whose cavities they occupy. In this way, too, the character of rocks may be essentially changed.

4. *Though the problem be often quite difficult, yet chemical geologists have been able to point out a great number of these metamorphoses in the rocks with much probability, by comparing the composition of the unchanged with the changed.* We give some examples:

Clay slate has been converted into mica schist, talcose schist, gneiss, and granite.

The origin of clay slate from clay is obvious to the most common inspection.

Almost any of the silicious sedimentary rocks can be converted into mica schist. Indeed, hand specimens of micaceous sandstones can hardly be distinguished from mica schist. This rock has also been derived from chlorite schist and from greenstone.

Mica may be produced from feldspar. That in sandstone was not improbably formed by the agency of meteoric water, subsequent to the deposition of the sandstone.

Talc, steatite, and chlorite, have been found to result from the decomposition of feldspar, hornblende, augite, garnet, mica, &c. The excess of silica in these minerals may have produced the quartz in talcose and chloritic schists.

Pulverulent carbonate of lime, such as chalk and marl, readily becomes crystalline or saccharoid, by being brought into a liquid condition, as is sometimes seen in the vicinity of trap dikes.

Bischof contends that dolomite, which is a double carbonate of lime and magnesia, is produced whenever there is "a permeation of carbonate of lime, by water containing bicarbonate of magnesia, which is one of the most common constituents of spring water." Hunt, of the Canada Survey, maintains that "dolomites, magnesites, and magnesia marls, have had their *origin* in sediments of magnesian carbonate, formed by the evaporation of solutions of bicarbonate of magnesia;" which solutions have resulted from the decomposition of sulphate or chloride of magnesia by bicarbonate of soda. (Am. Journal Sci., 2d Series, Vol. XXVIII., p. 383.)

Serpentine and other varieties of rock that come under the general denomination of Ophiolites, are essentially hydrous silicates of magnesia. Talc, chlorite, and steatite, have so nearly the same chemical constitution, that they may easily pass, and doubtless have often passed, into one another—more often probably from the schists into the serpentine than the reverse; and that too most likely in the wet way, although the serpentine is usually as unstratified as granite, and sometimes has in it distinct veins of chlorite—as at Newfane, in Vermont. Greenstone, or diorite, also passes into serpentine, which is probably formed out of it. Hornblende, feldspar, and mica, have likewise been converted into serpentine. In the very probable opinion of Sir William E. Logan, the abundant serpentines of the Green Mountain range have resulted from changes in silicious dolomites and magnesites. Other minerals and rocks might be named as capable of producing serpentine by metamorphosis; such as garnet, olivine, chondrodite, gabbro, &c. As it is one of the final products of mineral alteration, serpentine is one of the most permanent of rocks.

Quartz rock, being insoluble by water or acid, "appears," in the opinion of Bischof, "in all cases to be a product of the decomposition of silicates in the wet way." This opinion certainly seems plausible. But when we examine the mountains of almost pure compact quartz, certainly 1000 or 2000 feet high, it seems difficult to conceive how all the other ingredients could have been separated so entirely, and leave the quartz in such enormous solid masses; and hence we have suggested that some of it may have originated in silicious limestone.

The changes that are found to have taken place in the ores of iron are a good example of metamorphism. Starting with the carbonate, it is first changed into hematite, both hydrous and anhydrous; next into specular ore, and then into the magnetic protoxide.

Carbonaceous matter affords another good example. Peat, which is partially decomposed vegetable matter, is the first stage of the metamorphosis. This, permeated for ages by water, and covered by aqueous deposits, will become lignite, or brown coal. The next step develops bitumen, even without much increase of heat above the ordinary surface temperature. By still more powerful metamorphic action, the bitumen disappears, and leaves anthracite. A further step in the process produces graphite, or black lead, and perhaps the ultimate product is diamond.

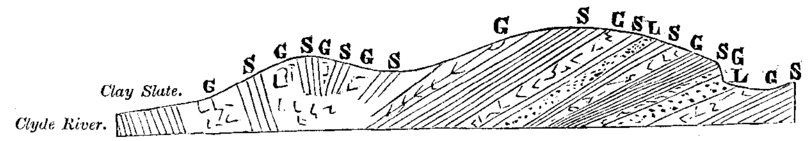
Change of slate, schistose rocks, conglomerates and breccias, into granitic rocks is metamorphism. Theory makes such changes quite possible and probable, and observation shows that they have been made, of which we have already given examples and details.

The following statements may be regarded as inferences from the doctrines of metamorphism as above developed.

1. *We see how it is that azoic schists may be interstratified with fossiliferous strata.* A few examples of this sort have been pointed out, especially in the Alps, where wedge-shaped masses of fossiliferous limestone, of liassic age, have been interlaced among the strata of gneiss. Indeed, strata of eocene tertiary have been converted into crystalline gneiss, mica schist, and even into granite beds. In our country not many analogous cases have been pointed out. We present one, which fell under our notice in the town of Derby, on the east shore of lake Memphremagog. The section in Fig. 19 will give an idea of this case as we understand it. Here, as we ascend a hill of moderate elevation, the strata

succeed one another in the following order: mica schist, granite, fossiliferous limestone (Devonian), granite, mica schist, granite, schist, limestone, schist, &c. Some of these masses, especially the granite, may be somewhat wedge-shaped, especially as we follow on in the direction of the section. The mica schist is highly crystalline, containing that peculiar species of mica denominated Adamsite, by Prof. Shepard.

Fig. 19.



Granite, Mica Schist, and Limestone. Derby.

Here we have highly crystallized granite and mica schist lying above limestone of Devonian age, in which we find encrinal stems, and it is scarcely at all crystalline. But this might take place, either by the greater fusibility of the super-imposed and intercalated beds, or possibly by a lateral permeation of heat and water.

2. *The process of metamorphism is still going on.* We see it more strikingly at the surface, especially in regions that have not experienced the erosions of the drift agency.—There the rocks are manifestly changed, often to the depth of several feet. But when we open the most solid rocks, or descend into the deepest mines, we shall find minerals undergoing alteration—new ones taking the place of old ones. Wherever water penetrates, even though the temperature be not raised, we may expect metamorphism. Indeed Bischof regards these changes as universal. "All rocks," says he, "are continually subject to alteration, and their sound appearance is not any indication that alteration has not taken place." (Vol. III., p. 426.) If it be so, it shows us how wide and difficult is the field which lies open for geological research.

3. *Metamorphism shows us that the earliest formed rocks on the globe may have all disappeared.* If we suppose, what geologists now generally admit, that the globe has cooled from a molten state, the earliest formed crust may have been a granite rock. True, this crust as a general fact has been thickening. But the process in many places, and perhaps alternately all over the globe, has been reversed. Suppose by the slow power of erosion, materials have accumulated in the bottoms of the oceans to a great thickness; the effect would be to cause the line of fusion to ascend, it may be so far as to melt off all the rocks originally deposited. In other places erosion might have worn off the upper part of this crust, and though this would cause the line of fusion to descend, and thus add new rock, yet between these agencies above and beneath, continued through countless ages, none of the first formed crust may remain. Or if any of it is left, it would be impossible to distinguish it from subsequent formations. So that the idea of a primary granite, or any other rock, in the strict sense of the term, has no foundation in nature.

4. *Metamorphism furnishes the most plausible theory of the origin of the azoic stratified rocks, which are mica, talc, and hornblende schists, gneiss, serpentine, white limestone, &c., such as cover a large part of Vermont.* The hypothesis that these rocks were deposited in a crystalline state, in an ocean so hot that the materials would crystallize, is not consistent with what we

now know of chemical geology; for water cannot hold in solution silicates enough for the purpose, nor does the order in which the materials are arranged correspond with that in which they would crystallize if they were in solution. No possible reason can be given, for instance, for the alternate layers of quartz and mica, or feldspar, or hornblende, or talc, which occur in the foliated rocks.

The theory of metamorphism has fewer difficulties. It supposes these rocks originally deposited as sand, clay, pebbles, marl, &c., after consolidation to have been converted again into a plastic state by the permeation of hot water and steam, charged with powerful chemical re-agents. We know that this agency is sufficient to bring the silicates into a sort of aqueo-igneous plasticity, and that is all that is necessary to produce the imperfect kind of crystallization which the azoic stratified rocks exhibit. It is not that complete crystallization which would result from thorough solution, either aqueous or igneous; but the original mechanical texture sometimes exhibits itself, and many degrees of crystallization are often manifest.

Some may be inclined to impute the hypozoic, and perhaps in general more highly crystallized foliated rocks, to some other agency than metamorphism. But we often find rocks of the same kind, and often as highly crystallized, so connected with fossiliferous rocks, that we are compelled to regard them as metamorphic, and it seems difficult to conceive that the others have not had the same origin. All the difference between the two classes, is the more complete metamorphism of the hypozoic. We seem compelled, therefore, to admit the metamorphic origin of all the azoic foliated rocks, or to deny it to them all; and we cannot take the latter ground but in defiance of the plainest facts.

5. *Metamorphism may have obliterated successive systems of life.* We know it to have done this in some of the foliated rocks—in the schists for instance—that overlie, or are interstratified with, fossiliferous rocks. It may have done the same with all the hypozoic, in all of which no certain examples of fossils have yet been found, though some bodies of doubtful nature have been described in them.

If this conclusion be admitted, it follows that we cannot tell when life first appeared on the globe, because we know not but an indefinite number of organic systems may have been obliterated. This inference, which some eminent geologists have adopted, would be fair, were it not for certain other facts, which we will state in the words of Sir Roderick I. Murchison. "In Bohemia," says he, "as in Great Britian and North America, the lowest zone containing organic remains, is underlaid by very thick buttresses of earlier sedimentary accumulations, whether sandstone, schist, or slate, which, though occasionally not more crystalline than the fossiliferous beds above them, have yet afforded no sign of former beings." "The hypothesis that all the earliest sediments have been so altered as to have obliterated the traces of any relics of former life which may have been entombed in them, is therefore opposed by examples of enormously thick and raised deposits beneath the lowest fossiliferous rocks, and in which, if animal remains had ever existed, some traces of them would certainly be detected." (Siluria, pp. 20, 21.)

6. *Metamorphism throws light upon the origin of the granitic rocks, such as granite, syenite, and perhaps some varieties of porphyry.* The prevailing opinion has been that they consist of melted volcanic matter, thrust into cracks in the overlying strata, and cooled and crystallized under great pressure and with extreme slowness. It is found, also, that other

rocks adjacent to the granitic, have suffered mechanical displacement, and such chemical changes as heat only could produce.

Now all these statements are to some extent true; and they show the presence of a considerable amount of heat, and some mechanical action by the granitic rocks. But more careful examination shows that granite does not generally form the axis of mountains, nor do the stratified rocks dip away from it on opposite sides, but often the granite lies between the strata, and instead of having been the agent by which they have been lifted up, it has only partaken of the general movement, which has resulted from some other and more general cause. Moreover the heat requisite to keep granite in a melted state, must be higher than it seems to have possessed; for Bischof says he could not melt it perfectly in the most powerful blast furnace. Again, if it crystallized from such fusion, the quartz would be first consolidated, because least fusible; whereas it is found to have been the last. Granite, also, contains not a few hydrated minerals, or such as must have been produced in the wet way, and its own ingredients can hardly have had any other origin. If now we admit the foliated rocks to have been brought into a plastic state by the joint action of heat and water, why not admit the same as to the granitic rocks; for often we cannot draw the line between them — between gneiss and granite, for instance. Their composition is the same and they differ only in the schistose or foliated structure, which often is so nearly obliterated in gneiss that we are in doubt whether it be present. What can granite be, then, but an example of metamorphism carried to its utmost limit? carried far enough to obliterate all traces of stratification, lamination and foliation? If water be admitted as a principal agent, heated by caloric from the earth's interior, and prevented from escaping by thousands of feet of superincumbent rock, complete plasticity would result at a temperature far below that required to melt granite in a dry state.

By this view a large proportion of granitic rocks may be only metamorphosed schists. If so, it explains why they have disturbed or changed the adjacent strata so little — the chemical influence rarely being traceable more than a quarter or half of a mile. In some instances they may have been thrown up from the melted interior of the earth, and possibly in a state of fusion without water. If only five or ten per cent. of water be present, it is calculated that the heat need not be so high as redness to produce the requisite plasticity.

If it be doubted whether water penetrates so deep into the earth's crust as we know granite to extend, it should be recollected that the stratified rocks — all of which were originally deposited from water, and, so far as we can judge, retain more or less of it still — are from ten to twenty miles thick. But, if even lava owes its fluidity in a measure to water, it may be supposed to be present in liquid granite with equal reason. In short, whoever admits the aqueo-igneous origin of the crystalline foliated rocks, will feel compelled to admit the granitic rocks to have resulted from essentially the same causes. Nor is this theory very different, after all, from that which has usually prevailed. It admits fluidity from heat in the materials, and only introduces water as an important auxiliary in the work. It is by no means the old Wernerian theory revived; for that made granite a deposit from an ocean.

7. *Metamorphism throws light upon the formation of dikes and veins, whether they belong to the granitic, trappean, or volcanic group of rocks.* It does this by introducing water along

with heat as an essential agent: for this agency will explain some facts in the history of veins and dikes, which, on the common theory of fusion from dry heat, were inexplicable. Thus, when we find veins not thicker than writing paper (and those of granite, epidote &c., are sometimes as thin, and some of trap are less than half an inch), it is difficult to see how they could have been filled by injection of melted rock, especially if the walls were not very hot; but by means of water the materials could be introduced wherever that substance would penetrate. Again, in the silurian rocks of Vermont, on the shore of Lake Champlain, we find numerous dikes, both of greenstone and trachytic porphyry. These dikes are in some cases partially filled with a conglomerate, or breccia, composed of limestones, sandstones, gneiss, quartz, and granite,—of the rocks in fact that occur in the region, as we shall describe in another place in detail. Now the limestone fragments have lost none of their carbonic acid. But this would have been driven off, as in a lime kiln, if the dike had ever been heated to redness, or to 1000° of Fahrenheit; for carbonates are decomposed below that temperature. This is all consistent if the partial plasticity of the dike was aqueo-igneous; but inexplicable if dry heat alone were concerned. Moreover, such dikes must have been filled mechanically from above, and this might have been done by the currents of an ocean, sweeping into the crevices on its bottom the rounded pebbles accumulated there.

8. *The facts of metamorphism teach us that most rocks have undergone several entire changes since their original production.* Take the unstratified rocks. These have all been cooled, and most of them crystallized from a state of fusion, either entirely igneous, or aqueo-igneous. Here is one change: but from the vertical movement of the isothermal line in the earth's crust, and the erosions at the surface, probably all the original igneous rock has been re-melted and re-cooled—much of it perhaps several times. If any rock has escaped this second fusion, we know not where it is to be found.

Take the stratified rocks. These being derived by abrasion from the unstratified, have of course passed through the just mentioned changes. But abrasion has brought them under another, a mechanical change, and water has collected the fragments together at the bottoms of lakes and oceans. Subsequently, by consolidation and some chemical agents, transfused by water through the mass, it has become converted into detrital fossiliferous rock. Buried afterwards beneath vast accumulations of other rocks, the heat has increased and hot water has permeated the strata, reducing them to a state more or less plastic, causing a crystalline to take the place of a mechanical structure, obliterating the fossils and substituting cleavage or foliation for lamination. In some cases the heat might be so great that all traces of stratification are blotted out, and granitic or trappean rocks are the result. It may be after all this, that erosion has again converted these rocks into detritus, and the process of deposition and of metamorphism begins again: nor can we tell how many times these changes may have been repeated. When they have passed through one cycle of change they are as fresh as ever to commence another.

9. *The final conclusion is, that the entire crust of the globe has undergone metamorphism, and is not now in the condition in which it was created.* We are sure that every part of it has been in a molten state; and we have every reason to suppose that every part of it has gone through other changes; nor is there any evidence that a portion of the first consolidated crust remains.

Men are accustomed to look upon the solid rocks as emblems of permanency. But in fact science teaches us that they are in a constant state of flux. They may be permanent when measured by the life of an individual; but when we compare their condition in the different and vast geological periods, change is the most impressive lesson they teach; and all those changes most wisely and beneficently ordered.

To give an idea of the extent to which rocks have been metamorphosed, we subjoin the following section of the stratified rocks, with the names on the right of the azoic rocks into which we know from reliable observation the fossiliferous to have been transformed. It must not be understood that the two kinds are generally interstratified, though they are sometimes so; but usually the azoic are proved to be identical with the fossiliferous by following the line of their strike and finding a gradual change from one into the other. Or when a part of a formation is found to be azoic, it is the lower part; and even though it be as high in the series as the tertiary, none but azoic rocks will be found beneath it. This shows that the metamorphic action is deep seated, and it may be that the granitic and trappean veins and dikes are connected with the molten interior of the earth. It is possible, indeed, to conceive that a bed of stratified rock may be converted into one unstratified, by heat and water permeating upward through a subjacent bed which is not so changed; in which case we should have granite and trap independent of the molten interior. But the record of geology gives us few examples of this kind, and the presumption, therefore, is, that the unstratified rocks require for their production a more powerful metamorphic action than could be communicated through any other rock, without producing a correspondent change in that also.

Alluvium.	
Tertiary.	Eocene Flysch changed into Mica Schist, Gneiss and Protogine.
Chalk.	Into Crystalline Limestone.
Oolite.	Lias into Mica and Talcose Schist and Gneiss.
Trias.	
Permian.	
Carboniferous.	Into Talcose Schist and Gneiss.
Devonian.	Into Clay Slate, Talcose Schist, Calciferous Mica Schist, Gneiss and Granite.
Upper Silurian.	
Lower Silurian.	Into Mica Schist, Talcose Schist, Gneiss and Azoic Limestone.
Cambrian.	Into Mica and Chlorite Schists and Gneiss.
Hypozoic.	
Granitic.	

According to these views an important practical question in respect to metamorphism is, what was the original rock from which the metamorphosed deposit was derived? In respect to the rocks of Vermont all other points are easy, compared with this. We shall do all we can to make out the identification, but, in not a few instances so complete has been the metamorphism, and so greatly have the strata been disturbed, that on the one hand we lose the clue with the newer and known rocks, and on the other cannot tell whether the rock we are examining may not belong to the oldest of the crystalline rocks, the date of whose metamorphism seems to have been earlier than the Silurian or perhaps even the Cambrian period. The facts we have detailed above, do indeed throw very much light on the process of metamorphism; but we feel by no means confident as to the age of the conglomerate which has furnished the data; and hence we are left in doubt as to the age of the associated rocks. We have other evidence, however, which makes it probable that most of the highly metamorphosed rocks of Vermont are altered Devonian and Silurian formations. In the western part of the State, and especially in that part of New York that lies southwesterly, we find these fossiliferous rocks but little altered, and these form a good starting point for the Green Mountain rocks and those farther east.

We regret that we have been obliged to make these preliminaries so technical, and to presume upon no little knowledge of geology in the reader. But no language less technical could explain the subject, and no one unacquainted with the leading principles of metamorphism can understand the rocks of Vermont. The course we have taken, therefore, seemed to be a kind of necessity. We now proceed to give a detailed description of the rocks of the State in such an order as we judge upon the whole to be best.

CLASSIFICATION OF ROCKS.

It may be desirable, before we proceed, to give an outline of the classification or order which geologists have adopted for the rocks. This has become, in consequence of the discoveries in respect to metamorphism, a matter of no small difficulty. The great outlines are indeed clear and satisfactory. To divide rocks into the stratified and unstratified, and then the stratified class into the fossiliferous and unfossiliferous, is natural, and is merely the expression of certain facts. But when we subdivide the stratified class further, it is very difficult to avoid terms that are based on theories that may be true or may not. This was the objection to the old division into Primary, Transition, Secondary, &c., and in consequence of this chiefly, they have nearly passed into desuetude. Some of the terms that have been proposed as substitutes seem to us not much better. Prof. Sedgwick proposed the name *Hypozoic* for such crystalline unfossiliferous rocks as lie below the fossiliferous. But in Vermont and other parts of the world some rocks of this kind lie above the fossiliferous. *Azoic*—that is, destitute of fossils—is not liable to these objections and is a far better term. The older slates and schists without fossils have been described by Sir Charles Lyell as metamorphic or stratified crystalline rocks. But why call these metamorphic when the term applies quite as well to a multitude of other rocks stratified and unstratified? Often, too, these are less crystalline than formations that lie above them.—Sir Charles also designates these rocks along with the unstratified that are crystalline as *hypogene* or *nether-formed*, and he says that "they never repose on strata containing organic remains." But we think we have Vermont granite and mica schist resting on fossiliferous limestone. Sir Wm. Logan describes metamorphic strata in Canada of great thickness and extent lying below the fossiliferous, which he calls Huronian; and below these analogous strata, the lowest of all, which he calls Laurentian. These terms, although local, are certainly unobjectionable; but as to their extent in Vermont we are able to say but little.

With so many difficulties to meet we have no ambition to try our hand upon a new classification of rocks, especially the crystalline schists; for there in fact lies the great difficulty, since all geologists are nearly agreed in regard to the outlines of the great groups. They are also agreed as to the number and character of the particular formations. So that really a diversity of views as to the grouping of some of the highly metamorphic strata is not of much practical consequence. Our chief object in the following outline, which we shall follow, is to avoid the difficulties which we have mentioned; though in shunning Scylla we may have fallen into Charybdis. The following list contains all the well known groups of rocks.

I. STRATIFIED, OR AQUEOUS ROCKS.

1. FOSSILIFEROUS.

a. *Cainozoic Period.*

1. Alluvium, embracing Drift.
2. Tertiary.

b. *Mesozoic Period.*

1. Cretaceous, with Green Sand.
2. Oolitic, or Jurassic, with Wealden and Lias.
3. Triassic, or New Red Sandstone.

c. *Palaeozoic Period.*

1. Permian.
2. Carboniferous.
3. Devonian.
4. Upper Silurian.
5. Lower Silurian.
6. Cambrian.

2. UNFOSSILIFEROUS, OR AZOIC.

1. Clay Slate.
2. Quartz Rock.
3. Mica Schist.
4. Talcose and Chlorite Schist.
5. Steatite, or Soapstone.
6. Serpentine.
7. Hornblende Schist.
8. Gneiss.
9. Crystalline Limestone.

II. UNSTRATIFIED, OR IGNEOUS ROCKS.

1. GRANITIC.

1. Granite.
2. Syenite.
3. Graphic Granite (Pegmatite.)
4. Protogine.

2. TRAPPEAN.

1. Greenstone, or Diorite.
2. Tufa, or Greenstone Ash.
3. Hornblende Rock.
4. Hypersthene.
5. Felstone.
6. Feldspar Porphyry.
7. Quartziferous Porphyry.

3. VOLCANIC.

1. Basalt.
2. Dolerite.
3. Amygdaloid.
4. Peperino.
5. Trachyte.
6. Trachytic Porphyry.
7. Pumice.
8. Tuff, &c.

In this country, as well as in Europe, several of the preceding formations have been subdivided into numerous subordinate groups, and in some cases these lesser divisions are used so frequently that we feel as if it was desirable to give them. This is especially the case in the fossiliferous rocks below the carboniferous, because these embrace nearly all the fossiliferous rocks in Vermont. Below will be found these formations, with their European and American divisions and thickness in feet, measured on a line perpendicular to the planes of stratification. The subdivisions are those employed in the geological survey of New York, because they have got into more general use than those more recently proposed by Prof. Henry D. Rogers.

Formations.	*European Divisions.*	*Thickness.*	*N. American Divisions.*	*Thickness.*
	Upper,		Catskill Red Sandstone,	5000
			Chemung Group,	3200
			Portage Group,	1700
			Genesee Slate,	300
			Hamilton Group,	600
DEVONIAN.	Middle,	10,000	Marcellus Shales,	300
			Upper Helderberg Limestone,	350
			Schoharie Grit, Cock-tail Grit,	300
			Oriskany Sandstone,	200
	Lower,			11,950
	Tilestone,	800	Lower Helderberg Limestone,	300
	Upper Ludlow Rock,	650	Water Lime Group, Onondaga Salt Group, Niagara Group,	1000
	Aymestry Limestone,	100		
	Lower Ludlow Rock,	1000		
	Wenlock Limestone,	300	Clinton Group,	2400
UPPER SILURIAN.	Wenlock Shale,	1500	Medina Sandstone, Oneida Conglomerate,	1450
	Woolhope Limestone,	50		
	Denbighshire Sandstone,	2000		
	Tarannon Shales,	1000		
	May Hill Group,	1000		
		8400		6150
	Lower Llandovery Beds,	1000	Hudson River Group,	2000
LOWER SILURIAN.	Caradoc Sandstone,	9000	Utica Slate,	500
	Llandeilo Flags,	5000	Trenton Limestone,	2500
	Lingula Flags,	5000	Chazy Limestone,	2500
			Calciferous Sandrock,	100
			Potsdam Sandstone,	300
		20,000		5900
CAMBRIAN.	Cambrian,	26,000	Huronian,	12,000
AZOIC.	Hypozoic,		Laurentian,	20,000

Some geologists describe rocks in a descending and some in an ascending order. Peculiar circumstances lead us to deviate somewhat from either of these modes. We propose, merely for convenience and not for the sake of scientific classification, to describe the rocks of Vermont in the four following groups:

1. ALLUVIAL AND TERTIARY ROCKS.
2. HYPOZOIC OR LAURENTIAN AND PALÆOZOIC ROCKS.
3. AZOIC ROCKS.
4. UNSTRATIFIED ROCKS.

The first group embraces all those loose deposits that occupy the surface, and whose description comes under the name of Surface Geology—excepting the Tertiary strata.—As these lie open to the inspection of all, and their position is not doubtful, their description may form a convenient introduction to the older rocks. In the second group we have a series of rocks commencing with the oldest known on the globe, whose relative age and order of superposition are clear, up to a certain height, and admitted by all geologists, and therefore these seemed to claim a description before the third group, which embraces rocks whose lithological characters are generally well marked, but whose true position in the geological scale is as yet quite uncertain. By this arrangement we begin with formations well known, and advance towards those over which much doubt and obscurity still hang. The fourth group is natural, embracing the decidedly unstratified rocks.

PART I.

ALLUVIAL AND TERTIARY ROCKS.

1. ALLUVIUM.

Under this term we include all the loose or partially consolidated materials, that have been worn from the older rocks at whatever period, and brought into their present state since the tertiary period. These materials, by whatever agencies first torn off from the solid ledges, have been mostly more or less sorted and deposited by water in layers or strata generally horizontal. The size of the fragments varies from that of enormous blocks, weighing thousands of tons, down to the impalpable powder of the finest mud.—In some instances certain ingredients have been dissolved out of the general mass, and separated by water, until evaporation has left them in the form of marl, bog iron and manganese ores, &c. These, also, belong to alluvium, and so does a consideration of all the geological agencies that have operated on the earth's surface since the tertiary period. In short, the number and variety of substances and of subjects embraced under Alluvium is very great, and we fancy that many persons will be surprised to learn how many agencies have been at work on the surface of Vermont at a comparatively recent date, geologically speaking.

What we include under Alluvium it has been usual to regard as two formations, the lowest of which is called Drift, and those deposits above it Alluvium. But since we regard the whole series to be the result of the same general causes with modified action, we cannot but consider the whole as a single formation. The lowest part, indeed, we call *Drift*, and the superimposed deposits *Modified Drift*. In treating of them we think we can give a clearer and more instructive view of their nature and origin, according to our notions, by commencing with Drift and ascending to the most recent Alluvium.

We embrace a description of the whole series under the term *Surface Geology*, which term has indeed only recently been introduced into geology, but seems greatly needed to embrace all those geological changes which the earth's surface has experienced since the tertiary period; indeed, as to one point, that of erosions, we would make it reach much farther back.

DRIFT.

We think it will not be difficult to give almost any inhabitant of Vermont an accurate idea of drift. For in almost every part of the State occur accumulations of bowlders, or large blocks of stone, with the angles more or less rounded, lying upon the solid ledges, or upon, or in the midst of, a mixture of smaller fragments, with gravel and sand; the whole mingled confusedly together, and evidently abraded by some powerful agency from the rocks in place, and driven along *pell mell* often to great distances: for if the bowlders and fragments be examined, they will for the most part be found not to correspond to the ledges beneath, but to others many miles perhaps to the north or northwest.

It is probable that if the whole State were denuded of its loose surface materials, the coarse mass of detritus which we have just described would be found almost everywhere, spread over the solid ledges. But as a matter of fact in most of the valleys and the level parts of the State, the surface trod upon consists of the same kind of materials in a finer state—in the form of gravel, sand, clay and soil. These are evidently for the most part drift, worked over and over again, and comminuted, mostly by water, and hence we call them *Modified Drift*. They lie above the true drift, and are the result of operations of posterior date. But where rivers or other erosive agencies have cut through the modified drifts, they generally disclose that which is unmodified beneath.

From these circumstances it happens that the unmodified drift does not form an extended surface deposit in but few instances, although almost everywhere it shows itself. Hence we have not thought it best to give it a place on the Geological Map. It is, however, spread over the higher portions (not the very crests and peaks) of the Green Mountains, especially in the southern part. And it is curious that it should be found so abundant at so great elevation. But we have evidence that no mountain in Vermont was high enough to escape the agency by which drift was produced, although some of the higher parts and ridges are too precipitous to retain the abraded materials upon their tops and sides.

But what was so remarkable an agency? We have often wondered why this question is not oftener put by intelligent men over the whole northern part of our country; for it is not in Vermont alone, but from Newfoundland to the Rocky Mountains, the same phenomena prove the former presence of the same powerful agency. Geologists have long and earnestly sought it out, and though they are not as well agreed on this as on most of the principles of their science, they have of late made a near approach to unity of opinion. But it will be desirable to go more into details as to the facts before venturing upon the theory.

FORM, SIZE, AMOUNT, AND POSITION OF BOWLDERS.

Sometimes we find bowlders with angles as sharp as if just chipped off from a ledge, and not at all exposed to the grinding action of other bowlders driven along by a force behind. But generally their rounded and often smoothed edges prove them to have been subject to such attrition for a long time. Indeed in many cases it is only the hardest kinds of rock that have been able to resist the grinding action to which drift has been subject, while the softer kinds have been ground to powder. Bowlders of the softer kinds of

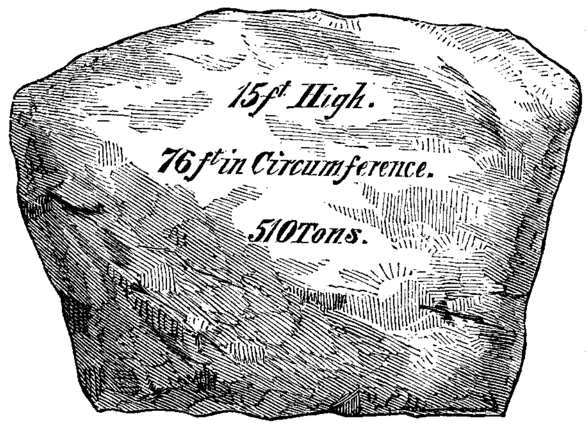
limestone, for instance, are rarely seen, even when we know from the direction in which drift was transported, that they must have been torn off from the ledges. Thus we know that the vast amount of drift covering the western slopes and higher parts of the Green Mountains was mainly derived from the valleys and lesser ridges lying west of those mountains; and although those valleys are mainly underlaid by limestone, yet fragments of it are rare among the hard blocks of quartz, gneiss, &c. of the drift. This fact, as well as the rounded form of most of the masses, shows that they were driven along the surface mechanically sometimes, although other facts show that they must also have been sometimes transported from one spot to another without touching the surface.

The great size and weight of these bowlders sometimes impresses the observer with the great energy of the force by which they were transported over deep valleys and up the sides of lofty mountains. I will give a few examples.

An inspection of the Geological Map will show a deposit of granite in the southwest part of the state, forming the high hill lying between Stamford and Pownal, which is almost as high as the Green and Hoosac Mountains east and southeast. Over those mountains the drift took a southeasterly direction. The consequence has been that all the western side of the Green and Hoosac Mountains is strewed over with bowlders of this granite. Indeed they extend southeasterly over the very hilly region in that direction, nearly across Massachusetts. It is a kind of rock easily distinguished from all others by its tendency to disintegration, by its blue quartz and the porphyritic aspect given to it by its oval foliated masses of feldspar. Being associated with quartz rock in Oak Hill, from whence it starts, bowlders of the latter rock accompany the granite in its dispersion. Nay, the quartz being much the hardest, its bowlders extend southerly much the farthest, being strewed over the whole width of Connecticut as well as Massachusetts, and not uncommon in the drift and modified drift of Long Island. But if any one wishes to get strongly impressed with the tremendous power exerted by the drift agency, let him pass up the hill west of Stamford towards Pownal, and he will be amazed at the accumulation and size of the bowlders, chiefly of granite, here almost covering the surface and preventing cultivation. We know of no place in Vermont better adapted to show the dynamics of drift than this, although many others of a striking character might be named.

There is one bowlder of this granite, however, which from its size and situation we would point out, although it has been carried a little distance over the line into Massachusetts. (Fig. 20.) Ascending Hoosac Mountain from North Adams into Florida on the Greenfield road, and turning northerly at its top so as to pass near the edge of the mountain a mile and a half in an unfrequented path, we come at length, in the midst of the woods, upon the huge bowlder of Stamford granite figured below from a hasty sketch. It lies nearly all out of the ground, resting on the ledges of slate beneath the thin soil. Its height is 15 feet, and it is 76 feet in circumference, weighing by estimation 510 tons. Few other bowlders are near it, and if the trees were cleared away it would be a striking object, especially if we turn our eyes westward and look into the valley running from Stamford southerly through Adams, and which is over 1300 feet deep. On its northwest side rises Oak Hill, which is some 200 feet higher than the bowlder, and where the granite is in place, from which some agency has torn it off and transported it many miles across the intervening valley 1300 feet deep. The fact seems the more striking because the western face of Hoosac Mountain is so steep that the idea of any agency pushing the bowlder along the surface is absurd. We see at once that it must have been lifted up and carried over the gulf. And then how happened it to be set down just on the edge of the mountain?

Fig. 20.



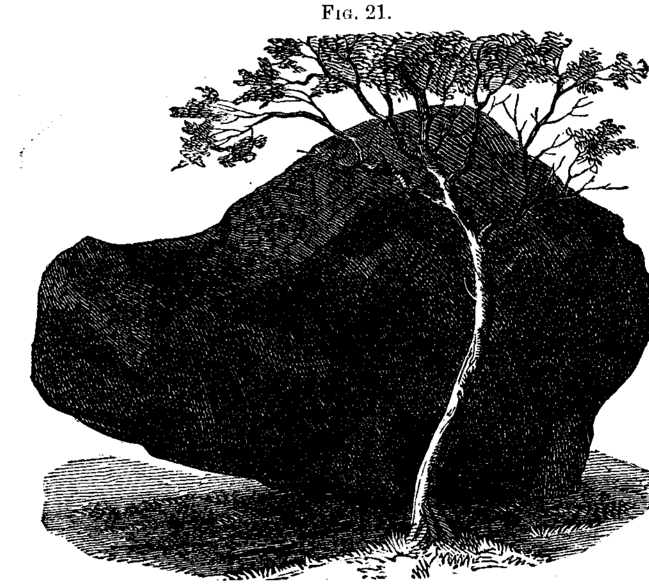
The Vermonter in Florida.

Such huge bowlders are beginning to excite a good deal of popular interest. One in Danvers, Mass., called Ship Rock, and weighing 1556 tons, surrounded by a multitude of smaller ones, has been purchased by a Scientific Society in Essex county, and an iron ladder attached to it. This is a commendable example; for in many parts of the country these bowlders will be used for building, as was done with perhaps the largest one in New England at Fall River, and thus some of the most striking proofs of the drift agency be destroyed. That in Florida will hardly be exposed to such a use, but we predict that not many years will elapse before it will be visited by travelers—especially as it lies not many miles from the Hoosac Tunnel—as an object of scientific interest. We hope there will be found public spirit enough in Adams to build a decent road to it, clear away the surrounding trees, and place a ladder against it, so that from its top — now inaccessible — a view may be obtained of the deep valley to the west, above described.

But though this child of Vermont has chosen its residence a little beyond the limits of the State, enough others remain within those limits of perhaps deeper interest. One in Stamford (12 feet high, 20 feet long and 18 feet wide) was used by an early settler as a buttress against which he built his house, and it now goes by the name of Rock Raymond. But the most gigantic specimen with which we have met, lies on the naked ledges on a high hill on the farm of Jonathan Dix, in the west part of Whitingham. From this hill we look westerly into the valley of Deerfield river, which must be over 500 feet deep, and from the character of the rock, corresponding to that of the Green Mountains (a highly micaceous gneiss), we feel sure that the bowlder was transported across this valley. Yet its length is 40 feet; its horizontal circumference 125 feet; its average width 32 feet; its cubic contents 40,000 feet, and its weight 3400 tons. Think of the power requisite in the first place to tear off from the ledge such a gigantic mass, and then to lift it up and carry it across a deep mountain valley, and then to plant it near the highest part of a rocky ridge. It does not seem to have been much rounded, and cannot therefore have been

subject to mere mechanical or aqueous attrition. Hence we suppose it to have been lifted up bodily and transported—not rolled—along with other fragments by a *vis a tergo*. The sketch below will give some idea of one of the sides of this bowlder An end view is quite different. It is situated in the midst of a forest and a little southeast of and below the crest of the hill.

Fig. 21.



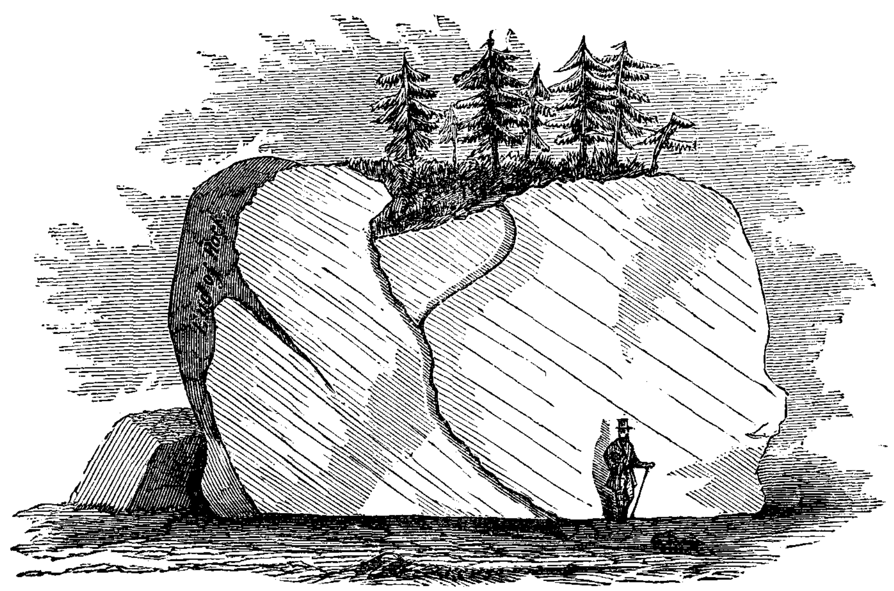
The Green Mountain Giant. 3500 tons, 41 feet long.

Until a larger bowlder shall be found, we propose for this one the name of Green Mountain Giant. It is the largest we have met with in New England, save one at Fall River—which is now destroyed for architectural purposes. The Giant should have a ladder attached to it, and the forest around it be cleared away, that persons of taste might be induced to visit it. Such objects are beginning to be incorporated into the world's literature, and we already have at least one volume entitled "The Bowlder," as well as Hugh Miller's Autobiography of a bowlder. Ere many years we predict that the Guide Books for summer tourists will describe the route to the Giant. When that shall happen we would recommend that those who visit it should extend their tour on the road from Whitingham to Hartwellville in Readsboro, to where it crosses Deerfield river at Readsboro Hollow, where they will find the bowlders very numerous and large. Under the bridge across Deerfield river lies one 25 feet long and 15 feet high, which weighs 478 tons, about equal to the largest in Great Britain. At a bridge over the west branch of Deerfield river beyond Readsborough Hollow, another bowlder may be seen of almost equal dimensions, as well as two or three others occupying a picturesque position in the village. If the west branch of Deerfield river be followed up towards Hartwellville, a succession of cataracts will be found for nearly five miles, and a great number of bowlders be seen uncovered of every size, which the drift agency has thrown down on this eastern slope of the Green mountains, and the river has developed.

In A. D. Hager's notes we find a sketch and description of an enormous bowlder, named by him Bingham's Rock, in the Smuggler's Notch at Stowe. He says that "Bingham's

Rock is 35 feet long, 25 feet high, and 21 feet broad, with spruce trees growing upon it 50 feet high. The east end of the rock, as seen from the north, is represented on Fig. 22 with a darker shading; and at its base a smaller bowlder leans against it. The diagonal lines represent the strata; the dark ones show projecting edges. On the top there is soil to support the vegetation upon it."

Fig. 22.



Bingham's Rock, in the Smuggler's Notch. Stowe, Vt.

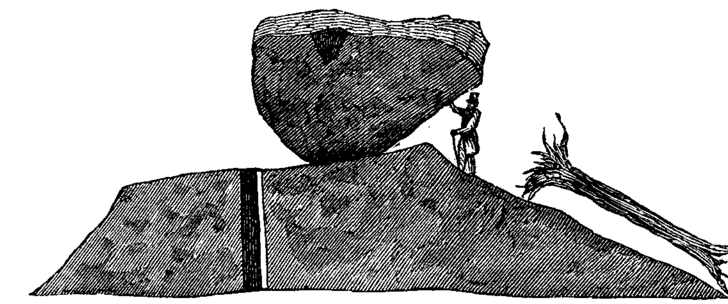
A little farther north than the above bowlder, is another which Mr. Hager calls C. Allen Brown's Rock. "It is five rods long, 25 feet high, and about 30 feet wide, and on the top of it are trees a foot in diameter. These blocks lie on the top of the ground and are isolated bowlders, which probably fell from the adjacent cliffs that rise upon either side to the height of 300 to 2000 feet."

Bingham's rock must weigh nearly 2600 tons, and Brown's rock 8300 tons. This last weighs more than the Green Mountain Giant. But as it is not probably a traveled bowlder, except to obey the laws of gravity in falling from the cliff, it can hardly be put into competition with the Giant.

We have already referred to the extraordinary display of bowlders in the west part of Stamford. We might add that along the west side of the Green Mountains, more especially towards their base, and in connection with the ranges of quartz, will be found surprising accumulations of bowlders on a strip at least one or two miles wide. Many of these appear to have become subject to a powerful action subsequent to the original movement that first tore them up and sent them southerly. The same is true of the accumulations in the northeast part of the State, which we have marked on the map as drift. At the lower levels in that region, they are decidedly modified drift. It is not easy indeed to say precisely where the line should be drawn between them, since both have been produced probably by the modified action of the same causes.

When bowlders are so balanced on their rocky support that the strength of a man can move them, they are called rocking stones. Some such have been found in Vermont.—We give below a sketch of one found among the papers of Prof. Thompson. The figure of a man and of an upturned tree show its size.

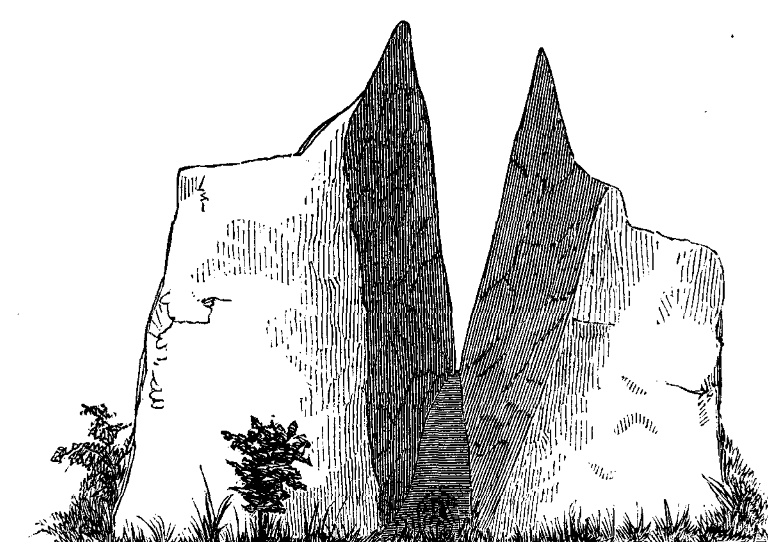
Fig. 23.



It is doubtless one of those figured by Prof. Thompson in the Appendix to his History of Vermont, p. 52. It weighs above 70 tons, yet is easily moved by the hand. It is in the town of Greensboro. There also is a bowlder 41 ft. long, 22 ft. high, and 22 ft. wide in its widest part—nearly equal to the Green Mountain Giant, in the same town.

Where fissures exist in these bowlders, water percolating into them freezes in the winter, and in the course of years splits them open. The parts by sliding along in wet soil and otherwise, sometimes get separated quite a distance. This is often imputed to some sudden and violent agency, whereas it has been the result of almost infinitesimal movements. The figure below represents one of these split bowlders of large size. Its whole length is 24 ft.; its width 20 ft., and its height 16. It lies on the south side of Winooski River, in Moretown, not far from the place where a bed of soapstone and serpentine runs southerly into the hill, say two miles east of the railroad station in Waterbury.

Fig. 24.



The following details respecting the dispersion of bowlders in different parts of the State are compiled from his field notes, by Charles H. Hitchcock :

"In passing from Brattleboro' to Bennington, about five miles west of the former place, we meet with great numbers of bowlders of a peculiar porphyritic hornblende schist. This rock is in place at Williamsville, in Newfane, and southerly from this place they can be traced across New England, decreasing in quantity and size. At Amherst the pebbles of modified drift are often porphyritic hornblende.

"The high region between Marlboro and Wilmington is covered with drift; some of the bowlders as much as six feet in diameter. Still more abundant and larger are they in Searsburg, on Deerfield River. There they are from twenty-five to thirty feet in diameter sometimes, and in great quantities. The drift agency, very probably conjoined with that of glaciers, has denuded the surrounding hills, so that in many places they are almost destitute of vegetation. The rock is a peculiar greenish variety of mica schist. Across the whole of Woodford the ledges of rocks are covered with drift, mostly of quartz and gneiss.

"The quartz bowlders along the western foot of the Green Mountains are appropriately called *hard heads*. In some places, as at North Bennington, houses are built of them by cementing them together with lime mortar. Except where they have been carried westward by a stream, as on the Walloomsac, these hard heads are not found west of rocks in place. This proves the force to have been from the north or northwest. If some seeming exceptions to this statement may be found,—as the quartz bowlders occasionally in the higher parts of Shaftsbury,—probably they originated in the Potsdam sandstone in New York.

"In Londonderry and Peru the surface everywhere is strewed over with bowlders of some variety of gneiss, but not very large. The same may be said of most of Windham County, where the common bowlders are usually not more than three or four feet in diameter.

"The top of Ascutney is destitute of bowlders, as we might expect. On the northwest and southwest sides of the mountain they are numerous, as well as in the valley between Ascutney and Little Ascutney. South of the mountain, through Weathersfield and Springfield, they are common, most of them corresponding to the granite and syenite of the mountains. On the hills of Cavendish and eastward to the Connecticut River, as well towards Bellows Falls, through Chester, they are quite frequent.

"The towns near Connecticut River, north of Ascutney, as at White River Junction, Norwich, Thetford, Strafford, and East Sharon, are pretty thickly covered with drift in the common form. In Hartford, bowlders of kyanite, and one of red iron ore from the region north of Burlington, were noticed. In Thetford and Pompanoosuc we find blocks with olivine and chrysolite. In Newbury occur bowlders some feet in diameter of that remarkable concretionary granite which is found in place in Craftsbury, Stanstead in Canada, and a few other places. They are found also in Ryegate and Waterford, of large size according to Prof. Thompson, and this fact awakens the inquiry whether this rock may not exist in places farther east than Craftsbury. Large bowlders of porphyritic hornblende schist, and a peculiar breccia are found also in Waterford, and the latter in Newbury. Between Guildhall and Canaan, for thirty miles, we meet frequently with large granite bowlders, and in general the northeast part of the State is strewed over with granite bowlders. In the valley of Passumpsic River, between Lyndon and St. Johnsbury, they are large and common, and they are specially so around Willoughby Lake. In some places over a wide space, as at West Victory, not a bowlder can be seen.

"Between Barnet and Marshfield, especially in the latter place, granite bowlders of large size are common. At Montpelier they are sometimes of gneiss, from a range of that rock in West Waterbury, the direction of the drift agency having been up the valley of Winooski. At a waterfall on that river in West Waterbury, a bowlder, perhaps twenty feet through, has fallen into a gorge, which is spanned by it, and the water passes beneath it.

"On the east side of Camel's Hump the bowlders are frequent, and a few foreign ones are found near the top. On Mansfield Mountain they are mostly angular and correspond in character to the rock of the mountain.

"The high land between Brandon and Rochester is covered with bowlders, some on the east slope quite large. Ten miles farther north we have in Ripton and Hancock interesting examples of what we regard as moraines of ancient glaciers. But these will be described in another place.

"Bowlders are not numerous in the valley of Lamoille River, except in East Georgia. Going east from St. Albans village we find them abundant. They are not infrequent over nearly the whole of Franklin county, and we find them scattered through the valley east of Jay Peak. Towards the south end of the valley south of Lowell we find modified drift, becoming coarser as we approach the gorge on the road to Eden. South of the gorge the bowlders are not numerous. Whether these facts can be explained on the supposition that the current that wore out this gorge came from the north, may be doubted.

"In the vicinity of Lake Memphremagog, bowlders at least five feet in diameter are strewed over the towns in Vermont, that lie south of the lake—the bowlders having come from Owl's Head and other places in Canada, and containing fossils. A bowlder some ten feet through, of a coarse breccia, may be seen on the Derby road in Brownington some two miles north of the Centre. Its home was in Canada.

"Along Lake Champlain bowlders are less abundant, especially where clay occurs, though they are sometimes mixed with the clay, as in West Charlotte. They are mostly from hypozoic rocks from New York and Canada, from pebbles to three and four feet in diameter — as along the shores of Georgia and Milton. South of Burlington the shore is rather free from bowlders.

"The bowlders on the islands in the lake where they occur, are of a similar character, as the following list will show.

Rock Dunder : Bowlders, hypozoic rocks, and Winooski marble.

Juniper Island : Hypozoic rocks, three feet diameter.

Lewis,
Hogback, } Mostly pebbles.

Valcour,
North Hero,
Grand Isle, } Generally small.

East side of Grand Isle,
Ladd's,
Savage,
Ball's,
Potter's, } From pebbles to 3 and 4 feet ; hypozoic rocks and Winooski limestone : Hypersthene abundant.

Knight's Island,
Potter's Island, } Have bowlders.

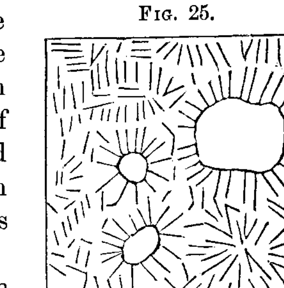
Kent's : Rocks in place ; Utica Slate.

Diadama Island : Sandy.

On the east shore of Isle La Motte are bowlders of hypozoic and metamorphic rocks.

In the north part of the town of Grand Isle are some large angular blocks (20 by 15 by 3 feet) of reddish encrinal limestone, which came from Isle La Motte, and are worn by water so as to have cavities of supposed horse tracks and boy's tracks.

Fig. 25.



"The fragments of slate along Lake Champlain, in some instances are curiously arranged. Where washed by the water along the beach you will see the slate radiating from the surface of bowlders, and sometimes without such a nucleus, as if so placed by man. The figure (Fig. 25) will give an idea of this arrangement. It is chiefly north of Burlington that it has been observed among the Hudson River and Utica slates. The most striking locality is in the southwest part of North Hero, near a fine locality of Graptolites, where this phenomenon is sometimes seen as perfect as in the figure.

"We are not aware that the facts noticed in the last paragraph have ever been described by geologists, although they certainly deserve attention. But until we have had opportunity to examine the phenomena further, we will not venture to throw out our crude speculations as to the mode in which the slaty fragments have been thus arranged."

TRAINS OF BOWLDERS.

Fifteen years ago we gave an account in the American Journal of Science, of some remarkable trains of angular bowlders, strewed almost in a strait line over the Taconic ranges of mountains southeasterly, some ten or fifteen miles, especially in the town of Richmond in Massachusetts. They were remarkable for not being rounded at all, for being strewed along as if by art in nearly straight lines, and with well defined borders, and also for lying above the common rounded bowlders. Subsequently they excited much interest, and were described anew by Prof. Henry D. Rogers and Sir Charles Lyell. In 1846 Prof. Adams discovered and described a similar case on land of Mr. Butts, in Huntington, Vermont, pointed out to him by Mr. Bunyan Bradley. One of our number has visited the place, but we prefer to re-produce Prof. Adams' figures (Figs. 26 and 27) and description, with a few slight corrections.

a h is a hill of talcose slate 150 feet high, and *g* a small hill of the same rock. *s y* is a narrow strip of syenite or perhaps hornblende rock, interstratified with the slate, numerous blocks of which have fallen into the valley below, *m n*, and are strewed over the highest hill and beyond it, as represented in figure 27, to *i k*, for a mile and a half. On the top of the hill are striæ, *d d*, running N. 15° W. as shown on the figure, and the line *p r* shows where the section (Fig. 26) crosses the two hills. That section will show the dip and position of the rocks and the bowlders.

Fig. 26.

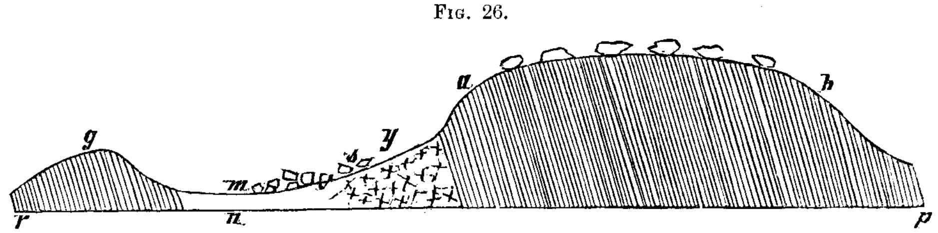
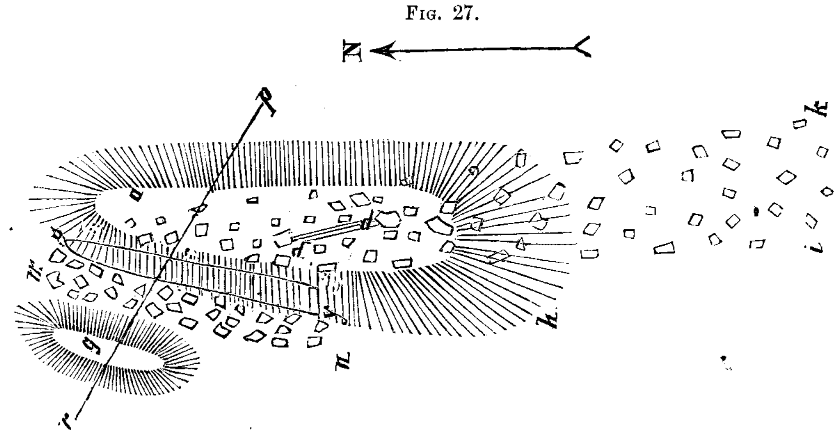


Fig. 27.



Prof. Adams suggests that probably similar cases occur in other parts of the State, and we agree with him in opinion. But in other cases which we have met, the bowlders are

more rounded, and there are not so distinct margins to the trains. One of us (C. H. H.) refers to East Williamstown, where the granite bowlders are numerous, for an example. We are not confident, however, that any of these cases ought to be regarded as the same with those at Richmond and Huntington.

Of all the phenomena of drift none have been more difficult to explain by any theories in vogue among geologists, than these trains of angular bowlders. To make water the sole agent, as some theories do, is the most unsatisfactory; for this could not alone have torn the blocks from their parent bed, and if it had been able to carry them forward at all, it must have rounded them. The most plausible resort would be to glaciers; but the nature of the surface over which the trains have been strewed, forbids the idea of a glacier. Common icebergs are no more satisfactory; but if we suppose islands capped with ice, and this occasionally torn up by the waves, and carried forward with fragments of rock in their under side, torn off from the islands and dropped along the way, or perhaps ice-floes in like manner frozen to the shore and torn off and urged along the coast, there is some plausibility in the explanation. But fully to set forth the arguments, pro and con, would require so much of detail as to the localities, that we judge it best merely to indicate our preferences among the theories that have been proposed.

We have sometimes been inclined to refer these "streams of stones" to what in Sweden are called Osar (or *osars* as we should anglicize the word, although *osar* is the regular plural in the Swedish language of *Os* which means "a pile of gravel"), and which occur also in Great Britain perhaps somewhat modified. These are streams of stones, gravel and sand accumulated behind obstructions, such as a ledge of rocks, or a stranded iceberg, and strewed along never more than a mile. But in Sweden these osars are confined to flat and level regions, whereas our *trainees* stretch over our mountains and valleys obliquely, and are many miles long, and are composed only of angular blocks. They may be varieties of the osars, but they must have been produced by greatly modified causes,—and we have not found in Vermont any genuine example of the European Os, if we may judge from description. (See Murchison's Geology of Russia, Vol. I., p. 540.)

STRIATION, PLANISHING AND EMBOSSMENT OF ROCKS.

If the immense masses of detritus that cover the surface in Vermont, containing bowlders weighing hundreds or even thousands of tons, have been driven forward either by water or ice, they must have left traces of their transit on the solid ledges. They have done so almost everywhere. Where the ledges have been exposed, however, for thousands of years, these markings have often, but not always, been obliterated by the disintegration of the surface. There is great difference in this respect between different rocks — some almost bidding defiance to the action of the elements, while others are easily eaten away. The calciferous mica schist that occupies so much of the eastern part of the State, is about the poorest for retaining the striation and planishing of the drift. Coarse granite and gneiss are about as bad. Crystalline limestone is quite as poor; while silicious limestone, such as occurs along the borders of Lake Champlain, has great power to resist decomposition. The upturned edges of clay slate are perhaps the best of all rocks to retain the markings. But if the soil be removed to a considerable depth from almost any rock, we may expect to find some evidence of drift action. If the whole of New England were denuded of soil, we doubt not that at least one half of its surface would be found covered with striæ, or smoothed, or with its prominences rounded. And we have often wondered why the numerous examples of these markings, which show themselves on the present surface, do not more forcibly arrest the attention of intelligent men and and excite inquiry as to the cause.

We have spoken of three forms of this phenomenon. The first is Striation. In this case after the surface of the rock has been ground down it is scratched, as if an enormous rasp had been firmly pressed upon it and steadily drawn forward; for the grooves or striæ are usually approximately parallel, although a second application of the same force may have produced a second set of striæ which cross the others at a moderate angle without obliterating them. It is more usual to find one set upon one part of a ledge, and another set upon the other part.

When the rock is very hard, or the drift materials very firm, the surface is only smoothed, but not striated. This we call *planishing*.

When the ledges were uneven with projecting points, the drift agency wore off the angles and rounded the salient parts, so that the surface presents protuberances like the bosses on a shield. This we call *embossment*. Where the protuberances are small and near together, they have been called by French geologists *Roches montonnes*—curled or frizzled rocks.

Of these different kinds of markings, striation is probably the most instructive. For by it we are able to determine accurately the direction taken by the drift agency. To this point, therefore, we have given a great deal of attention, and are able to furnish a full list of the courses of the striæ in different parts of Vermont. We have shown the same thing also upon the Map of Surface Geology. Such observations and such a map were commenced by Prof. Adams and continued by Prof. Thompson. The following Tabular View of the Drift and Glacier Striæ in Vermont (prepared by C. H. Hitchcock) will show to whom we are indebted and who is responsible for the observations. The map teaches the same thing as the table, but more impressively through the eye. This map, however, shows other striæ besides those of drift, which we refer to ancient glaciers; though some geologists look upon the common drift striæ as the result of glaciers. But in another place we shall point out certain differences which in our opinion indicate a diversity in the causes.

A TABULAR VIEW

OF ALL THE DRIFT AND GLACIER STRIÆ THAT HAVE BEEN OBSERVED IN VERMONT,

BY THE DIFFERENT GEOLOGISTS AND THEIR ASSISTANTS.

Where the same striæ have been observed by different persons, the name of the first observer only is recorded: and this is the case with most of those recorded by the earlier geologists, although their observations have been confirmed subsequently. These observations are recorded in the order of the sections—beginning at South Vernon, crossing the State to Pownal, then returning from Bennington across the State to Brattleboro, and so on zigzag towards the north part of the State. We have made no allowance

for the declination of the magnetic needle, but have copied the observations directly from our note books. The variation at the north-east corner of the State is 12° W., at the north-west part 11° W., as determined by the U. S. Engineers on the boundary line. At Burlington it is about 10° W., according to Professor Thompson. In the south part of the State the variation is 9° W. There is no record to show whether the observations of Adams, as copied below, have been corrected for the declination of the needle. We presume they have been corrected, as he was careful to make similar corrections in all compass observations, in his Reports.

DRIFT STRIÆ.

Locality.	*Kind of Rock.*	*Course of Striæ.*	*Remarks.*	*Observer.*
Vernon, N. E. part,	Clay slate,	N. 12° W.,		C. B. A.
Vernon, N. E. part,	Clay slate,	N. 3° W.,		C. B. A.
Vernon, N. E. part,	Quartz Rock,	N. 8° E.,	On the banks of Conn. River. Rocks adjacent for two miles N. and S., similarly situated.	C. H. H.
Guilford, N. E. part,	Clay slate,	N. 5° W.,		C. B. A.
Guilford,	Clay slate,	N. and S.,	N. Eng. Slate Co.'s quarry.	C. B. A.
Halifax,	Mica schist,	N. 20° E.,	Numerous at Tyler Wilcox's house. (Figured—2 sets.)	E. H.
Halifax, village,	Mica schist,	N. 20° E., and N. 10° E.,	Very fine exhibition of drift striæ in Halifax.	E. H.
Halifax, W. part,	Talcose schist,	N. 45° W.,	Glacial. (?) Numerous.	E. H.
Wilmington,	Talcose schist,	N. and S.,	Rock as flat as if a plane had passed over it.	C. H. H.
Wilmington, E. part,	Talcose schist,	N. 20° W., and N. 30° W.,	Intersecting.	C. B. A.
Marlboro,	Mica schist,	N. 28° E.,	Upon the high land.	C. H. H.
Marlboro,	Serpentine and hornblende schist,	N. 15° E., and N. 45° W.,	Intersecting.	C. H. H.
Marlboro,	Hornblende gneiss,	Stoss side N.—with roches moutones,	Without distinct striæ.	C. H. H.
Brattleboro,	Clay slate,	N. 8° W., and N. and S.,	Intersecting.	C. B. A.
Brattleboro,	Clay slate,		Mouth of West River, very fine. Found all along Conn. River for a great distance.	C. H. H.
Dummerston,	Clay slate,	N. and S.,	Numerous.	C. H. H.
Summit of Black Mt.,	Granite,	Rocks embos'd by a force N. 10°E.,	Upon flat rocks.	C. H. H.
Williamsville,	Mica schist,	N. 10° E.,	Also in the vicinity.	C. H. H.
Dover,	Talcose schist,	N. 45° W.,	Near John Sear's house.	C. H. H.
Wardsboro, E. part,	Talcose schist.	N. 30° E., and N. 30° W.,	Intersecting.	C. H. H.
Wardsboro,	Talcoid rock,	N. 10° W.,		C. H. H.
W. Wardsboro,	Mica schist,	N. 20° E., N. 10° E. and N. 10° W.	Intersecting. Angle of ascent, 12°—25°	C. H. H.
W. Wardsboro,	Mica schist,	About N. and S.,		A. D. H.
S. Wardsboro,	Mica schist,		Curious bend of striæ,	A. D. H.

Locality.	*Kind of Rock.*	*Course of Striæ.*	*Remarks.*	*Observer.*
S. Wardsboro,	Mica schist,	N. 10° W. and N. 20° E.,	Numerous. Very fine.	C. H. H.
Putney,	Clay slate,	N. 13° E. and N. 20° E.,	"Deflected by the valley, west."	C. B. A.
Rupert,	Clay slate,	West of North,	Very numerous.	C. H. H.
Windham,	Talcose schist,	N. 10° E.,	Near the glacier.	C. H. H.
Windham,	Talcose schist,	N. 20° W.,	On highest land in the region.	C. H. H.
Windham,	Talcose schist,	N. 20° E.,	In the valley near the centre of the town.	C. H. H.
Windham,	Talcose schist,	N. 15° W.,		C. B. A.
Townshend,	Gneiss,	N. 10° E.,		C. H. H.
Rockingham,	Clay slate,	N. 10° E.,	Numerous on Saxton's River.	C. H. H.
Rockingham,	Clay slate,	N. 5° E.,	Found at every favorable exposure of rocks, for miles along the Conn. River.	C. H. H.
Rockingham,	Do. and mica schist,	N. and S.,	On Williams River.	C. B. A.
Chester, N. part,	Gneiss,	N. 30° W.		C. H. H.
Ludlow,	Talcose schist,	N. and S.,		C. B. A.
Ludlow, E. part,	Talcose schist,	N. and S.,	On same ledge with glacier striæ.	C. H. H.
Andover,	Talcose schist,	N. 10° W.,	On height of land. Some striæ on perdendicular side of ledge.	C. H. H.
Andover, S. part,	Talcose schist,	N. 40° W.,	Running up a valley.	C. H. H.
No. Wallingford,	Conglomerate,	N. 50° W.,—N. 55° W.,	Those highest up are N. 55° W.	A. D. H.
Tinmouth,	Talcose schist,	N. 10° W.,	Near Colvin's quarry. On perpendicular side of ledge.	C. H. H.
Danby, S. part,	Limestone,	N. and S.,	On side of precipice, on Neoney hill.	C. H. H.
Reading, S. W. corner,	Gneiss,	N. 45° E.,	Running down a small valley.	E. H. Jr.
Fair Haven, W. part,	Clay slate,	N. 3° E.,		C. B. A.
Fair Haven, W. part,	Clay slate,	N. 15° W.		E. H. Jr.
Fair Haven,	Clay slate,	N. and S. and N. 30° E.,	At Myers & Otter's quarry.—Intersecting.	E. H. Jr.
Fair Haven,	Clay slate,	N. 10° E.,		E. H. Jr.
Fair Haven,	Clay slate,	N. 10° E.,		C. H. H.
Fair Haven,	Clay slate,	N. 3° E.,		C. B. A.
Castleton,	Clay slate,	N. 12° W. and N. 25° W.,	Intersecting.	C. B. A.
Poultney,	Clay slate,	N. 17° W.,		C. B. A.
Poultney, S. part,	Clay slate,	N. 10° W.,	Very numerous.	E. H. Jr.
Poultney,	Clay slate,	N. 7° W. and N. and S.,	Not intersecting.	C. B. A.

Locality.	*Kind of Rock.*	*Course of Striæ.*	*Remarks.*	*Observer.*
Wells,	Clay slate,	N. 10° W.,	Through the whole of the west half of the town very numerous.	C. B. A.
Pawlet, N. W. part,	Clay slate,	N. 10° W. and N. 34° W.,	Intersecting. The latter runs down a valley.	C. B. A.
Rutland, at P. O.,	Eolian limestone,	N. 10° W.,		C. H. H.
Norwich,	Mica schist,	N. 6° W. and N. 30° W.,	On Ct. River. Intersecting.	C. B. A.
Norwich,	Mica schist,	N. 8° E.,	Two miles west of village.	C. H. H.
Thetford,	Mica schist,	N. and S.	West part of town.	C. H. H.
E. Fairlee,	Clay slate,	N. 3° E.,	Numerous and fine.	C. H. H.
Fairlee,	Clay slate,	N. 5° W.,	On Conn. River.	C. B. A.
Bradford,	Talcose schist,	N. 10° W.,	Two miles north of village.	C. H. H.
Bradford,	Talcose schist,	N. 20° W.,	North part of town.	C. B. A.
Newbury,	Talcose schist,	N. 10° W. and N. 20° W.,	Intersecting.	C. B. A.
Newbury,	Talcose schist,	N. 3° W.,	Numerous.	C. B. A.
Mt. Pulaski,	Talcose schist,	N. 25° W.,	Near Newbury village.	C. H. H.
E. Roxbury,	Mica schist,	N. 20° E.,		C. H. H.
Braintree,	Talcose schist,	N. 15° W., N. 9° W. & N. 4° W.,		C. B. A.
Randolph,	Mica schist,	N. 6° W.,	½ mile east of the village.	Z. T.
Randolph,	Talcose schist,	N. 20° E. and N. 40° W.,	Intersecting.	C. B. A.
Rochester,	Talcose schist,	N. 32° W.,	Near Bethel line.	Z. T.
Rochester, E. part,	Talcose schist,	N. 21° W.,		C. B. A.
Warren,	Talcose schist,	N. 9° W.,	East town line.	C. B. A.
Warren,	Talcose schist,	N. 20° E.,	East part.	C. H. H.
W. Hancock,	Gneiss,	N. 40° W.,	See Fig.	C. H. H.
Middlebury,	Eolian limestone,	N. 10° W.,		C. H. H.
Middlebury,	Eolian limestone,	N. 4° E., N. & S., N. 5° W. and N. 20° W.,	In many different localities.	C. B. A.
Cornwall,	Slaty limestone,	N. and S.,	E. and S. E. parts of the town.	C. B. A.
Cornwall, S. part,	Argillaceous slate,	N. 3° W.,		C. B. A.
Salisbury,	Eolian limestone,	N. 20° W.,	North part.	C. B. A.
Salisbury, N. part,	Eolian limestone,	N. 10° E. and N. 12° E.,		C. B. A.
Whiting,	Eolian limestone,	N. 5° W.,		C. B. A.
Brandon,	Eolian limestone,	N. 15° W.,	Near village.	C. H. H.

Locality.	*Kind of Rock.*	*Course of Striæ.*	*Remarks.*	*Observer.*
Pittsford,	Eolian limestone	N. 10° W.,		C. B. A.
Hubbardton, E. part,	Clay slate,	N. 10° W.,	The striæ are very numerous and fine in all parts of the town. Intersecting.	C. B. A.
Hubbardton, N. part,	Clay slate,	N. 10° E.,		C. B. A.
Hubbardton, N. part,	Clay slate,	N. and S.,		C. B. A.
Hubbardton, S. part,	Clay slate,	N. 10° W.,		C. B. A.
Hubbardton, W. part,	Clay slate,	N. 20° W., N. 45° W. & N. 25° E.,		C. B. A.
Sudbury, N. part,	Clay slate,	N. 10° E.,	Numerous.	C. B. A.
Sudbury,	Clay slate,	N. 10° W. and N. 12° W.,	Numerous on top of a high ridge.	C. H. H.
Orwell village,	H. R. limestone,	N. and S.,		C. H. H.
Orwell, W. part,	Limestone, ?	N. 20° E.,		C. B. A.
Orwell, S. part,	Limestone, ?	N. 20° E.,		C. B. A.
Benson,	Clay slate,	N. and S.,	Numerous.	C. B. A.
Benson,	Clay slate,	N. 20° E.,		C. B. A.
Benson, N. W. part,	Clay slate,	N. 23° E.,	Very fine.	C. H. H.
Larrabee's Point,	Trenton limestone,	N. 12° E.,	On shore of Lake Champlain.	C. B. A.
Larrabee's Point,	Trenton limestone,	N. 20° E. also N. 12° E.,	General direction.	C. H. H.
Shoreham, N. E. part,	Limestone,	N. 33° W. and N. 20° W.,		C. B. A.
Crown Point, N. Y.	Chazy limestone,	N. 35° E.,	On east side.	C. B. A.
Crown Point, N. Y.	Trenton limestone,	N. 10° E.,	On west side.	C. B. A.
Chimney Point,	Trenton limestone,	N. 35° E. and N. 7° E.,	Intersecting.	C. B. A.
Bridport,	Utica slate,	N. 28° E.,	One mile south of Frost's landing.	C. H. H.
Addison, N. W. corner	Utica slate,	N. 25° E.,		C. B. A.
Addison,	Chazy limestone,	N. 5° W.,	Foot of Snake Mt.	C. H. H.
Weybridge,	Red rock,	N. 15° W.,		C. B. A.
New Haven,	Red rock,	N. 5° E. & N. 5° W., intersecting,	Near west town line, at a School House.	C. H. H.
New Haven, S. part,	Limestone,	N. and S.,		C. B. A.
New Haven,	Limestone,	N. 12° W.,		C. B. A.
N. Haven, S. W. part,	Limestone,	N. 3° W.,		C. B. A.
New Haven, E. part,	Red rock,	N. 10° E.,	Numerous. In one place on perpendicular side of a ledge—and even shelving over.	C. H. H.
Monkton, S. part,	Red rock,	N. 10° E..		C. H. H.
Monkton, S. part,	Red dolomite.	N. 25° E.,		C. H. H.

Locality.	*Kind of Rock.*	*Course of Striæ.*	*Remarks.*	*Observer.*
Monkton, S. part,	Oneida conglom'te,	N. 10° W.,	Middle of S. part.	C. B. A.
Waltham,	Limestone,	N. 18° W. and N. 5° W.,	Near Vergennes.	C. B. A.
Vergennes,	Chazy limestone,	N. 42° E.,	In a valley 20 ft. wide and 25 ft. deep.	C. H. H.
Starksboro, W. part,	Quartz rock,	N. 10° W. and N. 25° W.,		C. B. A.
Starksboro, N. part,	Quartz rock,	N. 33° W.		C. B. A.
Huntington,	Talcose schist,	N. 25° E.	At the train of bowlders.	C. B. A.
Huntington,	Talcose schist,	N. 25° W.,	S. E. of Do.	C. B. A.
Huntington, S. part,	Talcose schist,	N. 8° W.,		C. B. A.
Huntington,	Talcose schist,	N. 30° W.,	At Thomas Mix's house.	Z. T.
Huntington,	Talcose schist,	N. 48° W. and N. 68° W.	One half mile north of do., intersecting.	Z. T.
Huntington,	Talcose schist,	N. 31° W.,	South village.	Z. T.
Huntington,	Talcose schist,	N. 26° W.	One mile north of do.	Z. T.
Charlotte,	Oneida conglom'te,	N. 10° W.,	At the Baptist church.	Z. T.
Charlotte,	Oneida conglom'te,	N. 10° W.,	At J. A. Williams'.	C. B. A.
Charlotte,	Utica slate,	N. 12° W.,	N. W. part of the town.	C. B. A.
Charlotte, S. part,	Oneida conglom'te,	N. 10° E.,		C. B. A.
Charlotte,	Trenton limestone,	N. 7° W.,	At Mc Neal's point.	C. B. A.
Shelburne,	Oneida conglom'te,	N. 5° W.,	W. side of head of the Bay.	Z. T.
Shelburne, N. E. part,	Greenstone dike,	N. 20° W.,		Z. T.
Shelburne, S. part,	Limestone,	N. 15° W.,		C. B. A.
Shelburne, E. part,	Limestone,	N. 8° W.,		C. B. A.
Williston,	Talcose schist,	N. 8° W.,	S. E. part.	C. B. A.
Williston,	Talcose schist,	N. 20° W.,	1½ miles S. E. of the village.	Z. T.
Burlington,	Limestone,	N. 22° W.,	East part.	Z. T.
Burlington,	Red Rock,	N. 16° W.,	N. E. side of Shelburne Bay.	Z. T.
Burlington,	Utica slate,	N. 10° W.,	Appletree Point.	C. B. A.
Colchester,	Utica slate,	N. 10° W.,	Clay Point.	Z. T.
Essex,	Talcose schist,	N. 10° E. and N. 20° W.,	Intersecting.	C. B. A.
Essex,	Clay slate,	N. 31° W.,	½ mile east of the centre.	Z. T.
Essex Junction,	Talcose schist,	N. 33° W.,	Beginning to follow up the Winooski River.	Z. T.
Essex,	Talcose schist,	N. 24° W.,	1½ miles south of the village.	Z. T.

Locality.	*Kind of Rock.*	*Course of Striæ.*	*Remarks.*	*Observer.*
Essex,	Talcose schist,	N. 55° W.,	On Winooski River.	Z. T.
Essex,	Talcose schist,	N. 30° W.,	do	Z. T.
Jericho,	Talcose schist,	N. 44° W.,	do	Z. T.
Jericho,	Talcose conglom'te,	N. 40° W.,	do	C. H. H.
Richmond,	Talcose schist,	N. 60° W.,	Near Centre.	C. H. H.
Richmond,	Talcose schist,	N. and S.,		C. B. A.
Richmond,	Talcose schist,	N. 30° W.,	East part.	C. B. A.
Richmond,	Talcose schist,	Very variable, scattered and irregular.	Between Richmond village and Jonesville.	C. H. H.
Richmond,	Talcose schist,	N. 45° W.,	One mile west of Jonesville.	C. H. H.
Jonesville,	Talcose schist,	N. 45° W.,	Most remarkable place on the Winooski river for striæ and roches moutones.	C. H. H.
Jonesville,	Talcose schist,	N. 65° W., N. 45° W., and N. 38° W., intersecting.	The striæ change their courses, with the windings of the valley, but the stoss side is the north-west.	C. H. H.
Bolton,	Gneiss,	N. 45° W.,		C. H. H.
Bolton,	Gneiss,	N. 35° W.,	One half mile north Winooski River.	Z. T.
Bolton,	Gneiss,	N. 50° W.,	S. side of Winooski River.	C. B. A.
Bolton,	Gneiss,	N. 70° W.,	do. This direction is very common.	C. B. A.
Bolton,	Gneiss,	N. 60° W.,	North side of the river, very common.	Z. T.
Bolton, E. part,	Gneiss,	N. 62° W.,		Z. T.
Bolton, E. part,	Gneiss,	N. 80° W., and N. 80° E.,	South side of the river—passing into Duxbury.	Z. T.
Bolton, E. part,	Gneiss,	N. 60° W.,	North side of the river.	C. H. H.
Bolton,	Gneiss,	N. 35° W.,	On east town line.	C. H. H.
Waterbury,	Gneiss,	N. 63° W.,	North side of the river, very numerous.	C. B. A.
Duxbury,	Gneiss,	N. 68° W.,	Numerous.	C. B. A.
Sum't Camel's Hump,	Gneiss,	About N. W. and S. E.,	The summit illustrates beautifully stoss and lee sides.	C. H. H.
Waterbury,	Talcose schist,	N. 30° W.,	Two miles east of village.	C. H. H.
Waterbury,	Talcose schist,	N. 10° E.,	At village.	C. B. A.
Waitsfield, W. part,	Talcose schist,	N. 30° W.,		C. B. A.
Waitsfield, S. part,	Talcose schist,	N. 14° W.,		C. B. A.
Stowe village,	Mica schist,	N. 24° W.,		Z. T.
Stowe, E. part,	Talcose schist,	N. 24° W.,		Z. T.
Elmore,	Talcose schist,	N. 13° W.	One mile south of church.	Z. T.

Locality.	*Kind of Rock.*	*Course of Striæ.*	*Remarks.*	*Observer.*
Elmore,	Talcose schist,	N. 27° W.	Half mile S. W. of church.	Z. T.
Woodbury,	Mica schist,	N. and S. and N. 30° W.,		C. B. A,
Woodbury,	Mica schist,	N. 15° W.,		Z. T.
Wells River,	Mica schist,	N. and S.,		C. B. A.
Barnet & Waterford,	Talcose schist,	N. 5° E.,	In great abundance.	C. B. A.
Waterford,	Talcose schist,	N. and S.,	East part.	C. B. A.
Waterford, N. part,	Talcose schist,	N. and S.,		C. B. A.
Concord, W. part,	Talcose schist,	N. 10° W.		C. B. A.
Concord, E. part,	Talcose schist,	N. 10° E.	On Connecticut River.	C. B. A.
Kirby, S. part,	Clay slate,	N. 10° W.		C. B. A.
Kirby, S. part,	Clay slate,	N. 8° W.		C. B. A.
Kirby,	Clay slate,	N. 5° W.,	Middle of township.	C. B. A.
Lunenburg,	Talcose schist,	N. 3° W.,	Middle of township.	C. B. A.
Lunenburg, E. part,	Talcose schist,	N. and S. and N. 15° W.,	Intersecting.	C. B. A.
Guildhall, E. part,	Granitic gneiss,	N. 5° E.,	On Connecticut River.	C. B. A.
Guildhall, E. part,	Granitic gneiss,	N. 5° W.,	do.	C. H. H.
Granby,	Talcose schist,	N. and S.,	Striæ scarce in N. E. part of the state, on account of the easy decomposition of the rocks, and the great abundance of alluvial deposits upon them.	C. B. A.
Granby,	Talcose schist,	N. 20° W.,		C. B. A.
Granby, W. part,	Mica schist,	N. 5° E.,		C. H. H.
Victory,	Mica schist,	N. 10° W.,	A furrow.	C. H. H.
Maidstone, S. part,	Mica schist,	N. 10° W.,	On Connecticut River.	C. B. A.
Maidstone,	Mica schist,	N. 28° W.,	On Connecticut River.	C. B. A.
Canaan,	Mica schist,	N. 12° W.,	On Connecticut River.	C. B. A.
Canaan, N. E. part,	Mica schist,	About N. and S.,		C. H. H.
Stewartstown, N. H.,	Mica schist,	N. 3° E.,	A few rods from Vermont.	C. H. H.
Sheffield, E. part,	Mica schist,	N. 8° E.,		C. B. A.
Glover,	Mica schist,	N. 5° E.,	Middle of township.	C. B. A.
Greensboro, N. part,	Mica schist,	N. 10° E.,		C. B. A.
Greensboro, N. part,	Mica schist,	N. and S.,		C. B. A.
Greensboro,	Mica schist,	N. 10° E.,	On Craftsbury line.	C. B. A.
Craftsbury,	Mica schist,	N. 10° W.,	Near the middle of township.	C. B. A.

Locality.	*Kind of Rock.*	*Course of Striæ.*	*Remarks.*	*Observer.*
Lowell, S. E. corner,	Talcose schist,	N. 10° W.,		C. B. A.
Lowell, E. part,	Talcose schist,	N. 12° W.,		C. B. A.
Wolcott, W. line,	Talcose schist,	N. 45° W.,	Runs up valley of the Lamoille River.	C. B. A.
Hydepark,	Talcose schist,	N. 5° W.,	Near the previous set.	C. B. A.
Hydepark, S. part,	Talcose schist,	N. 8° W.,		C. B. A.
Hydepark,	Talcose schist,	N. 8° E.,		C. B. A.
Hydepark,	Talcose schist,	N. 25° W.,	On Lamoille River.	Z. T.
Morristown, N. part,	Talcose schist,	N. 10° E.,		C B. A.
Morristown, S. part,	Talcose schist,	N. 5° E. and N. 30° E.,	Intersecting.	C. B. A.
Johnson, E. part,	Talcose schist,	N. 70° W.,	This and the following run parallel to the course of Lamoille River Valley.	C. B. A.
Johnson,	Talcose schist,	N. 50° W.,		C. B. A.
Johnson,	Talcose schist,	N. 42° W.,		C. B. A.
Johnson, W. part,	Gneiss,	N. 30° W.,		C. B. A.
Johnson,	Talcose schist,	N. 20° E.,	Three miles north of the Lamoille, crossing a valley transversely.	C. H. H.
Cambridge,	Gneiss,	N. 75° W.,	Very numerous for three or four miles along the river.	C. B. A.
Johnson Centre,	Talcose schist,	N. 45° W.,	Near the river,	C. H. H.
Mansfield Mountain,	Gneiss,	N. 10° W.,	Summit of the Chin,	C. H. H.
Mansfield Mountain,	Gneiss,	N. 45° W.,	Between the Chin & Nose.	A. D. H.
Mansfield Mountain,	Gneiss,	Stoss side of certain ledges, N. 40° E.,	Summit of the Chin,	C. H. H.
Cambridge,	Talcose schist,	N. 33° W.,	Following up a slope of 40°.	C. H. H.
Cambridge,	Gneiss,	N. 60° W.,	Middle of township.	C. B. A.
Cambridge,	Talcose schist,	N. 25° W.,	Three-fourths of a mile from Lamoille River.	C. B. A.
Cambridge, N. corner,	Gneiss,	N. 5° W.,		C. B. A.
Cambridge,	Talcose schist,	N. 65° W.,	On Lamoille River,	C. B. A.
Underhill, S. part,	Talcose schist,	N. 17° W.,		C. B. A.
Underhill,	Talcose schist,	N. 10° W.,	Middle of township,	C. B. A.
Underhill,	Talcose schist,	N. 27° W.,	Near Union Village,	Z. T.
Westford,	Talcose schist,	N. 10° W.,	S. and Middle parts,	C. B. A.
Westford,	Talcose schist,	N. and S.,	N. and Middle parts,	C. B. A
Fairfax Falls,	Talcose schist,	N. 25° E. and N. 7° E.,		C. H. H.

Locality.	*Kind of Rock.*	*Course of Striæ.*	*Remarks.*	*Observer.*
Fairfax,	Talcose sandstone,	N. 25° W. and N. 34° W.,	East of village.	C. H. H.
Fairfax,	Talcose sandstone,	N. 8° E. and N. 8° W.,	Intersecting.	C. H. H.
Fairfax, N. part,	Talcose sandstone,	N. and S.,		C. B. A.
Fairfax,	Talcose schist,	N. 30° W.,	2¼ miles west of the village, on the river.	C. H. H.
Fairfield,	Talcose schist,	N. 15° W.,	Near the village.	C. B. A.
Fairfield,	Talcose schist,	N. 14° W.,	N. E. from village.	C. B. A.
Fairfield, N. E. corner,	Talcose schist,	N. 38° E. and N. 10° W.,	Intersecting.	C. B. A.
Fairfield,	Talcose schist,	N. 10° W.,	In great abundance same course to Enosburg.	C. B. A.
Bakersfield, S. part,	Talcose schist,	N. 5° W.,	Abundant.	C. B. A.
Bakersfield,	Talcose schist,	N. 7° W.,	N. and E. parts.	C. B. A.
Sheldon,	Talcose schist,	N. 15° W.,	On Missisquoi River.	C. B. A.
Sheldon Centre,	Talcose schist,	N. 35° W.,		C. H. H.
Enosburg,	Talcose schist,	N. 10° W.,	Very abundant from S. W. part of the town to the N. E. part.	C. B. A.
Enosburg, E. part,	Talcose schist,	N. 18° W.,		C. B. A.
Enosburg, N. E. part,	Talcose schist,	N. 47° W.,		C. B. A.
Enosburg,	Talcose schist,	N. 35° W.,	On Montgomery line.	C. B. A.
Enosburg, S. E. part,	Talcose schist,	N. 18° W.,		C. B. A.
Montgomery, N. W. p't	Talcose schist,	N 30° W.,		C. B. A.
Montgomery,	Talcose schist,	N. 70° W.,	"Deflected by Trout River valley."	C. B. A.
St. Albans Point,	Clay slate,	N. and S.,		C. B. A.
St. Albans E. part,	Quartz Rock,	N. 10° W.,	Top of hill.	C. H. H.
Franklin, N. part,	Clay slate,	N. and S. and N. 27° W., Intersecting.	Abundant.	C. B. A.
Franklin, E. part,	Talcose schist,	N. 40° W.,	On Canada line.	C. H. H.
W. Berkshire,	Talcose schist,	N. 35° W.,	Very fine.	C. H. H.
W. Berkshire.	Talcose schist,	N. 20° W.,	North part of town.	C. B. A.
Berkshire Centre,	Talcose schist,	N. 40° W., N. 25° W. & N. 8° W.,	Intersecting.	C. H. H.
Richford,	Talcose schist,	N. 80° E.,	On Missisquoi River.	C. H. H.
Jay Peak,	Gneiss,	N. 20° W.,	do. on N. W. side of Peak.	E. H.
Jay Peak,	Gneiss,	N. 40° W.,	On the summit, accompanied by furrows having the same direction.	C. B. A.
Potton, C. E.	Talcose schist,	N. 45° W.,	On the Missisquoi.	C. H. H.
Jay,	Talcose schist,	N. and S.,	At Missisquoi Falls.	C. H. H.

Locality.	*Kind of Rock.*	*Course of Striæ.*	*Remarks.*	*Observer.*
Troy, N. W. corner,	Talcose schist,	N. 15° W.,		C. B. A.
Newport,	Clay slate,	N. 70° E.,	Near Lake Memphremagog.	C. B. A.
Salem,	Mica schist,	N. 10° W.,	Near north line.	C. H. H.
Brownington,	Mica schist,	N. 25° E.,	East of the village.	C. H. H.
Brighton, W. part,	Mica schist,	N. and S.,		C. B. A.

DRIFT STRIÆ UPON ISLANDS IN LAKE CHAMPLAIN.

Valcour Island,	Chazy limestone,	About N. 15° W.,	South part.	C. H. H.
Straw Island,	Chazy limestone,	N. and S.,		C. B. A.
Providence Island,	Chazy limestone,	N. 13° W.,		C. B. A.
South Hero,	Chazy limestone,	N. 10° E.,	Sawyer's Bay.	C. H. H.
South Hero,	Trenton limestone,	N. 15° W.,	N. W. corner.	C. B. A.
Grand Isle,	Trenton limestone,	N. 10° E.,	Porter's landing.	C. H. H.
Grand Isle,	Trenton limestone,	N. 3° W.,	S. W. corner.	C. B. A.
Grand Isle,	Trenton limestone,	N. 3° W., and N; 10° W.,	S. part on W. shore.	C. B. A.
Welden's Island,	Utica slate,	N. and S.		C. B. A.
Isle La Motte,	Chazy limestone,	N. 14° E., and N. 45° E., Intersecting.	Fisk's Quarry.	C. B. A.
Isle La Motte,	Chazy limestone,	N.10°E.&N.30°E.,Intersecting.	Cook's Quarry.	C. B. A.
Isle La Motte,	Chazy limestone,	Eight different sets,	Hill's quarry.	C. B. A.
		N. 8° E.,	Those running N.10°W., are the most common; next the two sets N. 20° W. and N. 30° W.	
		N. 3° E.,		
		N. 10° W.,		
		N. 25° W.,		
		N. 43° W. and N. 45° W.		
		N. 47° W., and N. 65° W.,		

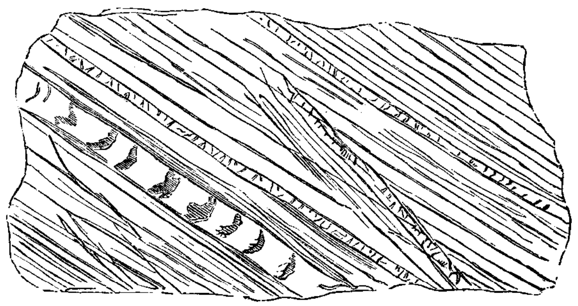
GLACIER STRIÆ.

Searsburg,	Gneiss,	N. 25° W.,	Variable in direction.	C. H. H.
Searsburg,	Gneiss,		Varies with the course of the valley; shown especially on the stoss sides of the rocks.	C. H. H.
Newfane, N.W. part,	Gneiss,	N. 53° W.,	On branch of West River.	C. H. H.
Windham,	Talcose schist,	N. 10° W.	Sources of Saxton's River.	C. H. H.
Grafton,	Gneiss,	South sides of ledges stoss.	On Saxton's River.	C. H. H.

Locality.	*Kind of Rock.*	*Course of Striæ.*	*Remarks.*	*Observer.*
Jamaica, S. W. part,	Gneiss,	Stoss sides various.	On a very crooked branch of West River.	C. H. H.
Jamaica village,	Gneiss,	N. 80° E.,		C. H. H.
Ludlow, E. part,	Talcose schist,	N. W. and S. E.,	On the same ledge with drift striæ.	C. H. H.
Mt. Holly, E. part,	Gneiss,	N. 60° W.,		C. B. A.
Mt. Holly, E. part,	Gneiss,	N. 50° W.,		E. H. Jr.
Plymouth, N. part,	Talcose schist,	N. 50° W.,	On a tributary of the Otta Quechee.	C. H. H.
Stockbridge,	Talcose schist,	N. 30° W.,	Accompanied with many others varying from it.	C. H. H.
Rochester,	Talcose schist,	N. 20° W.,	On White River.	C. H. H.
Rochester,	Talcose schist,	E., and W.,	On west branch of White River.	C. H. H.
Rochester,	Talcose schist,	N. 43° E.,	At village.	C. H. H.
Granville,	Talcose schist,	N. 24° W.,		C. H. H.
Hancock village,	Talcose schist,	N. 30° W.,	Another branch.	C. H. H.
Hancock, west of do.	Talcose schist,	N. 80° E., and N. 75° E.,		C. H. H.
Hancock, W. part,	Gneiss,	N. 70° E.,	Associated with drift striæ N. 40 deg. W.	C. H. H.
Huntington.	Talcose schist,	N. 46° W.,	"Deflected by mountain gorge."	C. B. A.
Huntington, W. part,	Talcose schist,	N. 30° W.,		C. B. A.
Huntington, W. line,	Talcose schist,	N. 27° E.,	Force from S. W.	C. H. H.
Huntington, N. part,	Talcose schist,	N. 16° E.,		C. H. H.
Mansfield Mt. west side of chin.	Gneiss,	N. 48° W.	A recent slide. Angle of descent from 35 to 25 deg.	C. H. H.

The striæ that have been described, differ in size from the finest scratch visible up to a furrow a foot deep. The largest single groove we have seen with the dimensions just indicated, occurs in hard limestone in Whiting, a few miles south of Middlebury, on the west side of the main road. This furrow is several feet long. But the most remarkable grooves we have seen, when we consider their length, were observed on the Missisco River, just after the river passes out of the Troy valley northward into Canada. On the west side of the river and of the road, within the limits of Potton, and at the northeast side of Jay Peak, the talcose slate shows itself in ledges, rounded by a force directed southerly, or up the stream, and there we found striæ six inches wide, three inches deep, and three or four rods long. The rock is very hard, and the force which could have ploughed out such deep and straight furrows must have been enormous. Generally the scratches are less than half an inch deep.

Fig. 28.



Another evidence of the powerful force exerted upon the planished surface is seen, when instead of simple furrows a strip of some breadth exhibits a succession of chips partially started up, as if the abrading agency did not exactly cut its way but moved over the surface with a jarring motion. This is finely shown upon some of the dark limestones on the shores of Lake Champlain, and of which Fig. 28 will give an idea.

We noticed another curious fact on the same specimen. A pebble evidently got loose between the grinding body and the ledge, and waddled off to one side; but was soon so completely crushed that all trace of it, as shown on the figure, disappeared. This fact establishes the important conclusion that the striating body was large and unyielding, and had fixed projecting points on its under side, which were made to plough straight furrows. Hence over very uneven surfaces the scratches usually retain their parallelism, even when running obliquely along quite steep slopes. For had the fragments which made the grooves been loose, beneath a heavy moving body of any kind they would have waddled off laterally, as in the above example, and consequently the striæ would not have been parallel.

PREDOMINANT COURSES OF THE STRIÆ.

Local variations in the direction of the striæ are quite common. But the inquiry has often arisen whether we can discover more than one predominant course, which would indicate any general change in the direction of the drift agency. Connecting the facts brought to light in the Vermont Survey with those previously known of other parts of the country, we venture to point out three predominant directions taken by the force at different times.

1. FROM THE NORTHWEST.

We might perhaps conclude these striæ to have been made the earliest because we find them generally upon the highest mountains. And the force by which they were produced—an arctic ocean as we judge—then overtopped the mountains bearing icebergs on its surface, which struck against the highest points. As the waters sunk, so that the hills appeared and valleys were formed, the direction of the currents, and consequently of the striæ, was modified. So far as we have facts (we wish we had more) the grooving and planishing force (which means with us the direction of the oceanic currents) was turned more towards the east when the country was all beneath the waters, than afterwards. The following courses of the striæ on the high ridges of Vermont and Massachusetts will, we think, make this opinion appear probable.

Mansfield Mountain, summit of the Chin, 4348 feet high,	N. 20° W.
Jay Peak, 4018 feet high,	N. 40° W.
Camel's Hump, 4083 feet high,	N. 40° W.
Mount Holly, 1415 feet high,	N. 60° W.

Windham, highest land,	N. 30° W.
Ripton,	N. 50° W.
Dover, high,	N. 55° W.
Newfane, highest land,	N. 63° W.
Wardsboro,	N. 40° W.
Plymouth,	N. 60° W.
West Halifax,	N. 55° W.
Several high peaks in Massachusetts, on the Hoosac range (Geological Report, p. 388),	N. 45° W. to N. 70° W.
West side of the Taconic range across Massachusests,	N. 45° W.

Some cases, we are aware, can be quoted where the direction on very elevated ground is more nearly north and south. And the cases are numerous, as the table we have given will show, where it is as much deflected towards the east as in the above table, in the lower and more level parts of the State. A part of these cases we explain by the supposition of ancient glaciers following down the valleys; other cases show the modifying influence of valleys, of which the valley of Winooski River is a striking example.—And then if icebergs did the work, we might expect that some of the largest would reach the surface of the low and level parts of the country when the ocean was the highest. But upon the whole we cannot doubt that one of the predominant and most powerful or the striating agencies took a south east direction. Any one conversant as a geologist with the west side of the Green and Hoosac Mountains, must have been struck with the strong marks exhibited by their western slopes of the mighty force that must have long beaten against them, covered them with detritus, and scored their surface. No ridges that we have ever seen in New England show any such marks on their eastern side.

2. FROM THE NORTHEAST.

The evidence is much less striking, of a drift agency coming from the northeast across Vermont and Massachusetts than from the northwest. Nevertheless, we have discovered too many cases of a force from that direction and passing over some of our highest land, to be able to refer it to ancient glaciers or local deflection. We quote the following cases:

Mansfield Mountain, stoss side of some ledges on the Chin, about	N. 40° E.
Marlboro, high land,	N. 38° E.
Morristown,	N. 30° E.
Windham, in valley,	N. 30° E.
Johnson,	N. 30° E.
Halifax Centre,	N. 10°, 20 and 60° E.
Putney,	N. 20° E.
Mt. Pocomptuc, Heath, Mass., 1888 feet high,	N. 30° E.
Southampton, Connecticut valley, sandstone,	N. 60° E.
Granville, 1240 feet high,	N. 60° E.

Most of the above cases occur along the eastern slope of the Green and Hoosac Mountains, so that a force coming from the northeast must have urged the materials obliquely up hill, since these mountains coincide nearly with the meridian, and the northeast side must have been the *stoss* or struck side—and such we find to have been the case. Perhaps the most striking example of this sort, is the top of Mt. Pocomptuc, nearly 1900 ft. high, a few miles south of the Vermont line, in Massachusetts, where we find the rock striated by a force coming from N. 30° E. Farther south, in Southampton and Granville, the direction was still more towards the west, as it was in Halifax, Vermont.

At the west, around Lake Superior, and still farther west, the evidence of a southwest direction to the drift current is very striking, as shown by Foster & Whitney, and others. Connecting the western examples with those in Vermont and Massachusetts, the conclusion is plausible that a current once came up the Gulf of St. Lawrence, when the country was beneath the ocean, bearing along the icebergs that striated the rocks. It may be that the period of this northeast current was earlier than that from the northwest, since the striæ running northeast and southwest are less distinct than the others and are seen in fewer localities. But we think further and more careful observation are necessary to decide the question.

3. FROM THE NORTH.

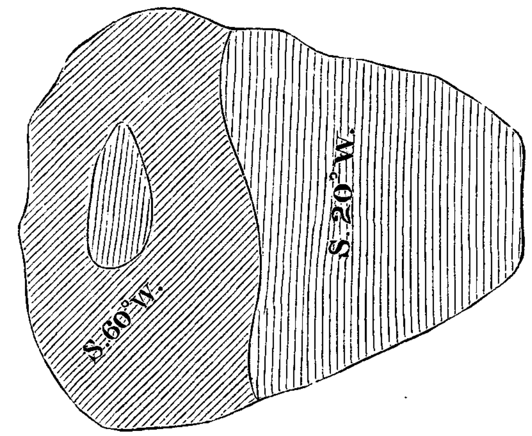
These are more abundant and distinct than the other sets. They occupy the valleys mostly, and are generally rather more fresh and distinct than those upon the highest mountains. We are of opinion that they were formed mainly when the ocean, then covering the surface, had so far subsided as to force the water into the valleys. These have for the most part a nearly north and south direction, and therefore the striæ, produced by the icebergs which were confined within them, have the same direction. It is quite clear, however, that the force which produced the striation, where not diverted, tended southeasterly. For the average deviation in the valleys, as our Table shows, was several degrees east of south; whereas the average bend of the valleys is a little west of south; and, moreover, we find the largest quantity of detritus almost always lying on the west side of the ridges. But the most decisive evidence on this point is seen in the Winooski and Lamoille valleys. These run N. W. and S. E., and cross the Green Mountain range, and everywhere on their bottoms and sides the striation is very distinct, while the rounded side of the ledges is the northwest side, showing without question that the grinding body moved southeasterly, or up the streams. From all these facts we infer that while the general tendency of the abrading force was southeasterly, the valleys turned it southerly by diverting the waters— and consequently the icebergs—of the retiring ocean in that direction.

The striæ of the Champlain valley, as we conceive, present us with interesting examples of the abrading action of ice from the remote period of the drift until the present. We find not a few examples here, as the table will show, of striation from the northeast — perhaps the oldest of all the scratches, as we more and more incline to believe. These along the lake, pointing in that direction, may have resulted from local deflection; but more probably are of the same age as the northeast system on the east side of the Green Mountains. The more usual course along the lake is somewhat east of south. But on the immediate shores we sometimes find an unusual variety of courses on the same surface. Prof. Adams has noted eight at Hill's Quarry on Isle La Motte, viz., N. 3° E., N. 8° E., N. 10° E., N. 25° W., N. 43° W., N. 45° W., N. 47° W., N. 65° W. On the limestone in Shoreham, where the surface passes under the lake at low water, the striæ are

very fine and vary considerably in direction, in a few cases as much as 90°. Some of the striæ in such cases are also very fresh, and we can easily believe that some of them may have been made by the expansion of the ice of the present lake, which along the shore may have pebbles frozen into it, and when subsequently crowded eastward from the centre of the lake, or lengthwise of the same by the wind, striation may have been the result. If so, this work may have been going on from the time when huge icebergs were borne southerly by the ocean, when it extended from the Gulf of St. Lawrence to the bay of New York,—when most of New England, as well as Essex county, N. Y., was an island, or group of islands, and the direction of the currents and the icefloes was modified by the projecting ridges. As the water decreased the friths would gradually change into lakes, and the icefloes and icebergs into fixed sheets of ice, which, in the spring, might be lifted up and moved southerly by the current, leaving traces of its movement on the abraded rocks. Thus the present striæ may be the resultant of all that have been made from the drift period to the present time.

The same reasoning will apply, *mutatis mutandis*, to the striæ in the Connecticut valley, which for the most part have the same direction, with a southeasterly tendency, and which are seen in some cases passing beneath the water at its lowest mark. Very likely some of these may have been produced by ice floods at a modern period in the history of the river. Yet in general the distinction between river action and drift action, is very obvious—as, for instance, at Bellows Falls.

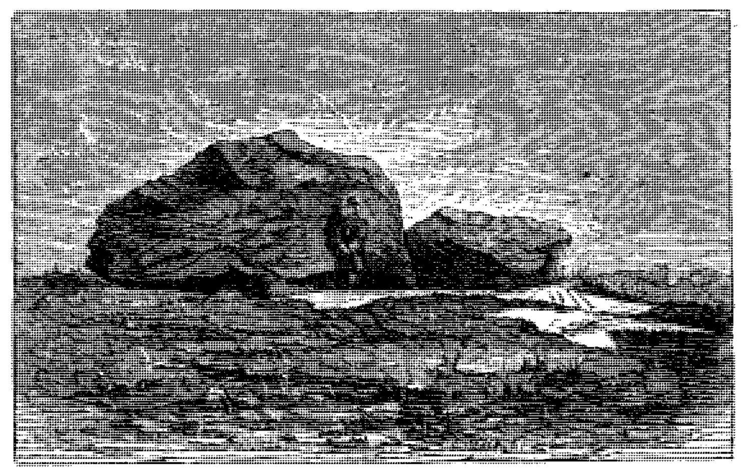
Fig. 29.



In Halifax, which in the central part is almost as high as the Green Mountains, drift striæ are unusually distinct and abundant. Here we have at least two directions on the same limited surface, as is shown on Fig. 29, sketched from a rock a few feet in diameter, about two miles northeast of the centre.

A. D. Hager has furnished an interesting sketch from a stereoscopic view of some bowlders, and *the striæ made by them*, on Mansfield Mountain. (Fig. 30.)

Fig. 30.



Some other cases of striæ in Vermont remain to be described, which we have been in the habit of referring to ancient glaciers, in distinction from the drift agency. But these will be better understood if we previously make a few remarks upon

PLANISHING AND EMBOSSMENT.

We have already stated that planishing or smoothing of the surface has taken place where the rock is quite hard, or the materials quite fine. The hardness is also favorable in general to the preservation of the rock. Hence quartz rock and silicious limestone often exhibit a smoothness scarcely inferior to artificial polish. A level surface is perhaps most favorable for the exhibition of this variety of the phenomena of abrasion. Yet it is often shown very finely on embossed surfaces. In this variety there must be a considerable inequality of surface, and it is the rounding of the angular protuberances which constitutes the embossment. Consequently as it was done by some body urged over the surface, one side of the elevations would be rounded more than the others. This struck side is called in Sweden the *Stoss* side, and its opposite in English the *Lee* side, or the sheltered side, which rarely shows any abrasion. This distinction is very important, for it enables us to determine the direction of the abrading force.

Most frequently the embossed surfaces are striated. Yet when the striæ are all obliterated by disintegration, the rounded form of the bosses and the distinction between the stoss and lee sides remains; so that this variety of the drift agency is the most permanent of its mementos. It occurs also on the grandest scale: for often a large mountain constitutes a single boss. Indeed most of the mountains in the northern parts of our country owe the rounded form of their summits—so different from those in the Alps, for instance—to this agency.

STRIATION, PLANISHING, AND EMBOSSMENT BY ANCIENT GLACIERS IN VERMONT.

Glaciers are vast rivers of ice, which, starting from the snow-capped summits of lofty mountains, move slowly down the valleys as far as the heat of summer will permit them. Though they rarely ever advance more than two feet a day, even in summer, yet their great thickness and the weight of the superincumbent snow cause them to grate hard upon the rocky surface beneath; and they do, in fact, produce all the phenomena of striation, planishing, and embossment, which have resulted from drift. Nor can the two classes of phenomena be distinguished by anything in their appearance. But glaciers also crowd along huge masses of detritus, from the largest bowlders down to impalpable powder, which are called Moraines. The moraine in front of the glacier often nearly fills the valley to the height of 100 or 200 feet, and the lateral moraines are scattered along the sides of the valley.

In many parts of Europe, as Wales and Scotland, those striæ and moraines are found in such circumstances as to indicate the former presence of glaciers where they have not existed within historic times. It has long been an interesting inquiry whether any similar markings exist on any of the mountains of this country. To the White Mountains we should naturally look for such phenomena: but the explorations there have not had much success. The Green Mountain range, including Hoosac Mountain, which is a continuation of the Green Mountains across Massachusetts, has afforded more satisfactory results. The evidence of ancient glaciers on that range was first found in the town of Russell, in Massachusetts, described in a paper on Surface Geology, in the Smithsonian contributions to knowledge. The same paper contains an account of other cases on the main branch of Westfield river, on Deerfield river, and on the branches of Quechee river, above Woodstock, in Vermont. Other cases have come to our knowledge, during the survey of the latter State, of a still more decided character, which we shall now describe. They are also exhibited on our Map of the Surface Geology.

It ought to be premised in this connection that some able geologists regard all the phenomena of drift as produced by glaciers. Such, of course, make no such distinction between the different varieties as we do. The difficulties in the way of referring all the drift phenomena in our country to glaciers seem to us insuperable, and we therefore resort to icebergs for common drift, and refer such cases as have the following characters to glaciers.

1. Glacier striæ differ often widely in direction from drift striæ, and the stoss side of the ledges is of course very different in reference to the cardinal points.

2. Glacier striæ occur only in valleys radiating outwardly from crests of mountains, while the drift striæ overtop the mountains, and when found in valleys frequently cross them obliquely.

3. Glacier striæ descend from higher to lower ends, except in limited spots, where they may be horizontal. Drift striæ frequently ascend mountains hundreds of feet high, whose stoss side is the lower side.

4. Drift is spread promiscuously over the surface, and the blocks are a good deal rounded. The detritus of glaciers more or less blocks up the valleys, or lies strewed along the sides of the valleys, and the fragments are frequently quite angular. These blocks, however, are sometimes covered more or less with materials that have been modified by water, flowing for ages down the same valleys.

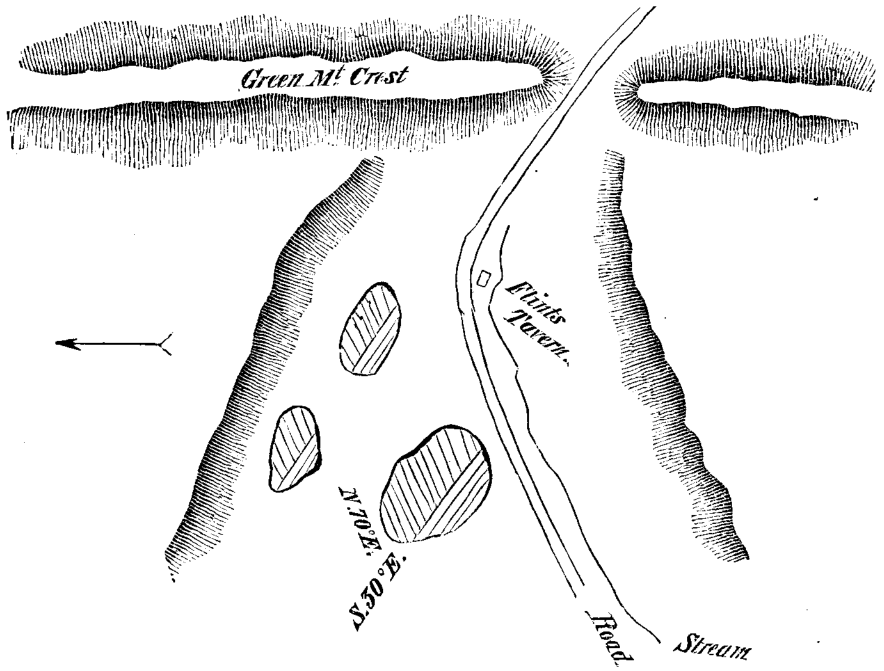
Guided by these principles we give the following examples of what we regard as cases of ancient glaciers in Vermont. In regard to some of them we still feel in doubt, partly because we have not been able to give them the requisite investigation.

Perhaps the most satisfactory cases of this sort occur on the road across the Green Mountains through Ripton and Hancock to Rochester. We follow a branch of Middlebury River through Ripton till we arrive within half a mile of the depression in the crest of the Green Mountains, where the Hancock road crosses. Here, a little to the left of the road, and 117 feet below its summit, we find embossed ledges of rock on which are two very distinct sets of striæ, the one running S. 50° E. pointing toward the depressed portion of the mountain crest, with the stoss side on the northwest; the other set pointing W. 30° S. or down the valley, with the stoss side on the northeast. Hence the two sets cross each other at an angle of 70°, or more properly speaking their direction differs 110°, the force by which the first set was made pointing S. 50° E. and the other S. 60° W. The force by which the first set was produced was up hill towards the crest of the mountain, which a few miles to the north of the road we judge, without measurement, to rise 800 to

1000 feet above the striæ. The force producing the second set was down hill in the direction taken by a small stream.

The rock most strikingly scored by these opposite forces is represented on Fig. 31. But there are others in the same vicinity, somewhat higher up, which present the same double striation, and which are exhibited in the annexed Map, Plate VIII., Fig. 1, which shows a region on both sides of the crest of the Green Mountains, where we suppose are the marks of ancient glaciers: on the east side on the branches of White River.

Fig. 31.



The case of doubly striated rocks on the west side of the mountain near the line between Ripton and Hancock, is a remarkable example of the juxtaposition of drift striæ and those which we must regard as produced by a glacier passing down a valley towards Middlebury. We can explain it by no other supposition, and this does meet the case exactly. It is the only example where we have found a valley on the west side of the Green and Hoosac Mountains which seems to have once contained a glacier. Generally the valleys on that side are very short and steep, and there seems hardly room for a glacier.

As we pass over the crest of the mountain from the spot above described, on the Hancock road, we strike and pass down a branch of White River. As we emerge from the forest into the cleared land we begin to meet with striæ in the bottom of the valley, pointing N. 70° E., the upper side of the ledges being the stoss side, and therefore the agent of erosion was directed down the valley. In three places also, before reaching the main branch of White River, we found accumulations of detritus, stretching across a considerable part of the valley, in the same manner as we find ancient terminal moraines in the valleys of the Alps. We cannot doubt that these in Vermont, which are shown—perhaps not exactly in their true places, as we made no measurement of distances—on the accompanying Map, had the same origin. They may in some instances have been more

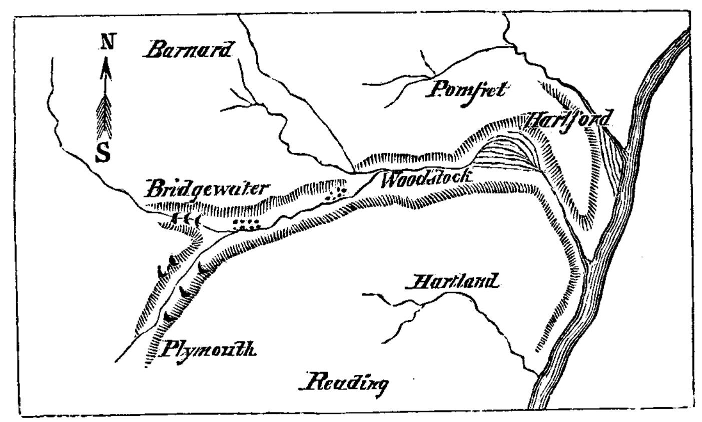
modified by the subsequent action of water upon their surfaces than those of the Alps; but their internal character seems to us to be the same.

In descending the main branch of White River (see Map) we find evidence, even as far down as Stockbridge, that a glacier once descended the valley; for the striæ change their direction in conformity with its direction, and although the course does not differ much from some examples of drift in the same region upon the hills, yet the conformity of the striation to the course of the valley, while it is quite different in the side valleys which come in from the Green Mountains, looks more like a glacier or rather a system of glaciers. On the South Branch similar striæ occur, conforming even more strikingly to the sinuosities of the valley, and resulting probably from another glacier. In Granville, also, we found similar striations, as the map shows. As we pass southerly out of the village of Hancock, the mountains approach, and between them stands a hill of considerable height, which is beautifully rounded. This is precisely the spot where a descending glacier would grate most powerfully upon the ledges beneath.

We regret our inability, for want of time, to explore the branches of White River more thoroughly for evidence of glacier action, which we doubt not will hereafter come to light.

Another example of the traces of the action of ancient glaciers, not so striking, however, as those already detailed, occurs on the Quechee River above Woodstock. In ascending that stream above that village we meet, within a mile or so, accumulations of detritus on the north bank, which we refer to moraines that have been subsequently considerably modified by water. Several miles farther west we found a still more decided example, just before reaching the village of Bridgewater. Here the detritus seems once to have extended entirely across the valley, but has been worn away by the river on one side, as we see in the vicinity of Chamouni in Savoy, where we are certain that glaciers were the cause. The only difference seems to be that in Vermont water has subsequently produced greater modification than in the Alps.

Fig. 32.

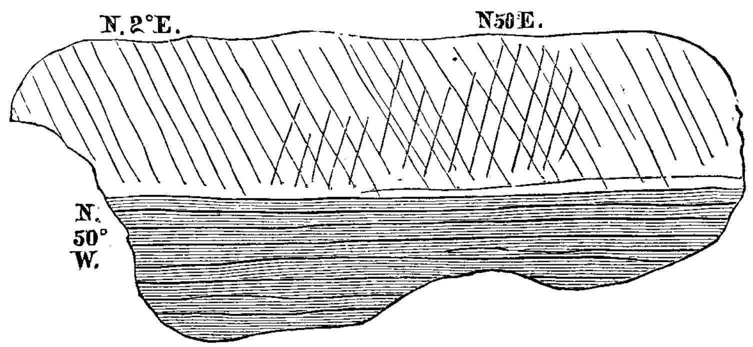


Traces of a Glacier on the Otta Quechee.

In following up the south branch of Quechee River, which comes in from Plymouth, we find the west and southwest sides of the mountains to be rounded, though the striæ seemed to be mostly obliterated. On the more northerly branch of the river, at least as far as the gold mine in Bridgewater, where an auriferous quartz vein has been worked, we found the west side of the hills to be the stoss side, as it would be if a glacier once descended from the crest of the Green Mountains down the valleys of Quechee. And though our explorations have been far more limited than we could wish in that region, we strongly incline to the belief that a system of glaciers once occupied the head valleys of the Quechee as well as those of White River, as exhibited on Fig. 32.

Black River takes its rise in the northwest part of Plymouth, near the head of a branch of the Quechee. Black River runs south through the whole of Plymouth, and to the middle of Ludlow, where it turns easterly through Cavendish, Weathersfield, and Springfield, to the Connecticut. Between Ludlow and Proctorsville, say a mile and a half east of Ludlow, on the north side of the road, a rock is exposed, a little more than a rod in length and only four or five feet high, on whose top are developed two sets of drift striæ; one—the most distinct—running N. 2° E. by the needle, and the other N. 50° E. But on the perpendicular face of the rock is another set of striæ, running in the direction of the valley, viz., N. 50° W. and S. 50° E., as shown on the sketch below (Fig. 33.) It seems impossible to account for these striæ, especially the last named, without supposing a glacier once to have descended the valley, which however has a very gentle slope. In following the valley northerly, we meet with no other sign of a glacier till we reach the long pond in Plymouth, say eight miles north of Ludlow. This pond is long and narrow, and towards its north end is entirely divided by a mass of detritus of sand, gravel and bowlders, having exactly the appearance of the terminal moraine of a glacier. The shores of the pond elsewhere are remarkably free from detritus, and this causeway, over which a road passes, is only a few rods wide. The valley is narrow and the sides quite steep. If this was not the moraine of a glacier, we can hardly hope to convince the public that there are any in Vermont. It is situated only a little north of some of the best gold diggings in Plymouth, and at the foot of the remarkable quartzose conglomerate with flattened pebbles, that has been described. Indeed, the objects of geological interest that are grouped together near this spot are unusually numerous.

Fig. 33.



We have noticed some examples of striæ and moraines of a similar character on the branches of the Deerfield River, before it enters Massachusetts, after which they are quite striking. In some other places along the eastern slope of the Green Mountains, insulated cases of like character have been seen; and indeed we little doubt that in all the valleys which descend easterly from the crest of the Green Mountains, the marks of ancient glaciers may be found.

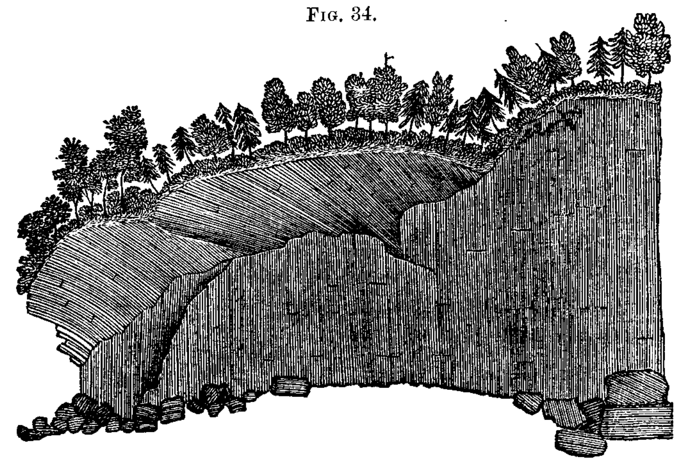
We suppose the period when these glaciers existed to have been that in which the continent was sinking for the last time previous to the drift period beneath the ocean; or more probably when it was emerging. The amount of ice brought over the surface by a northern current during this submergence, must have so lowered the temperature that glaciers might have capped any summits rising even moderately above the ocean.

Even those geologists who suppose all the drift phenomena to have resulted from enormous glaciers, will have no difficulty in admitting the occurrence of these minor glaciers, crossing the track of the principal ones, during some part of the glacial period, through which all will admit the northern parts of our country have passed.

FRACTURED AND CRUSHED LEDGES OF ROCKS.

Nearly thirty years ago, in a Report on the Geology of Massachusetts, we described a bending and breaking down of the layers of clay slate at the quarries in Guilford, as if by an enormously heavy pressure from above, and a movement towards the west, of a heavy body, as is shown on Fig. 34. This exhibits from 10 to 15 feet in the upper part of Bruce's quarry, on the west slope of the hill, but extending probably to the top, bent or broken down, so that the plates of slate slope at all angles from 0° to nearly 90°. Their normal position is a westerly dip of about 80°. The crushed edges of the slate appear for a considerable distance along the east side of the valley wherever the soil has been removed near the top of the hill, and the effect was evidently produced by some force acting near the top of the hill and directed downward or westward into the valley. So far as we can judge, the very top of the hill has not been affected, though very probably it was crushed originally, and that the fragments have been subsequently swept away from a spot so exposed, while on the side of the hill they remain as first crushed down.

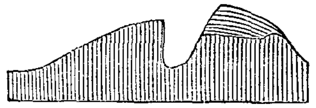
Fig. 34.



In Professor Adams' second annual Report, he describes another case at Willard's quarry, three miles northeast of Bruce's quarry. Here not only are large quantities of the broken slate lying at various angles on the east face of the quarry, but behind these a quantity of the layers have been bent into a zigzag form, and though loose, they still retain their parallelism. This is an important fact, because it shows that the effect must have been produced by a heavy pressure on the top of the hill.

Prof. Adams mentions another case in the southeast corner of Brattleboro, where the laminæ have been bent over in nearly the same direction as at Bruce's and Willard's quarries, for the depth of only three feet. He also describes the same phenomenon in two other quarries in Dummerston, belonging to Mr. T. Clark, only fifty or sixty rods apart. He thinks, however, that the direction of the crushing force here must have been nearly opposite to that in Guilford and Brattleboro. Recently, however, we found at the Dummerston quarries a spot (whether one of those described by Prof. Adams we cannot say) where the force seemed to be from the east, as shown on Fig. 35. The disturbance, so far as we could see, extended only two or three feet vertically.

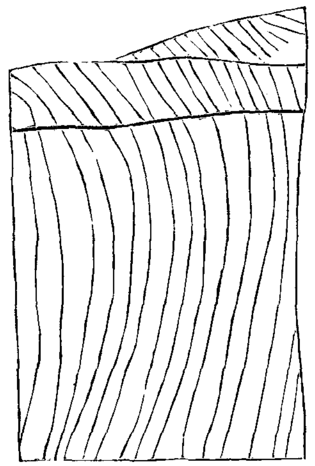
Fig. 35.



An analogous case of fracture and crushing was found on the Western Railroad in Middlefield, Mass., in hornblende schist, and described in the Massachusetts Final Report with a figure (p. 396.) Also another case, less in vertical extent, within the city of Lowell, in gneiss, discovered in the grading of a street by Dr. S. L. Dana.

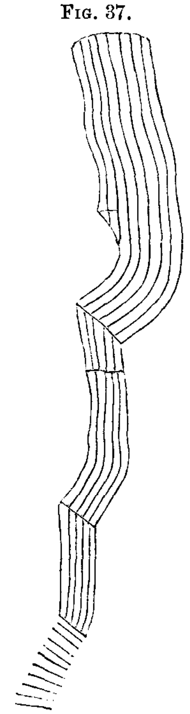
During our researches in Vermont, other analogous cases have come under our observation. One of these is in one of the clay slate quarries in Northfield. It is on the north side of the ravine along which the quarries are opened, and the accompanying sketch will give some, though a very imperfect, idea of the appearance of the edges of the slate, which here have a westerly dip not far from 75°, but which are bent and fractured at the upper part quite as much as represented on the figure. The force here must have pressed downward and westward as at Guilford.

Fig. 36.



A still more remarkable case occurs at Newbury, two and a half miles north of the village, where is a deep railroad cut through a variety of talcose schist. The hill is a spur, forty or fifty feet high, lying on the west side of the meadows, and its narrowest part shooting out northerly. The strata here, whose normal position is nearly perpendicular, have been very much bent, broken, and crushed, to the depth say of thirty feet, which the railroad cut opens. It is difficult to convey any correct idea of these disturbances by the sketch, as the faces of the rock laid bare coincide nearly with the strike of the strata. The annexed imperfect oblique view of one spot on the west side of the cut, (Fig. 37), will show something of the flexures, fractures and crushing, to the depth of twenty feet. Sometimes the folia are bent at right angles without any fracture. This may not have taken place wholly at the same time with the fractures, as in other cases already described,—at Bruce's quarry of clay slate in Guilford, for instance,—where movements of plication along the nearly perpendicular joints seem to have taken place at an earlier date than the fracturing force, and the bent laminæ are rarely broken.

Fig. 37.



Still, at Newbury it is difficult to exclude the bent strata from those fractured, as to their origin.

One of us (C. H. Hitchcock) represents the overlying limestone at the Rutland marble quarries to be very much fractured, so much so as to be useless as marble.—Some force acting at the surface seems to have done this work. Prof. James Hall, in his Report on the New York Survey, has given a very instructive section of an extensive disturbance of this kind near Niagara Falls, which nothing but a powerful lateral force can explain. We have seen several similar examples at the red sandstone quarries near Newark, in New Jersey, where the thick beds have been in some places broken into fragments and crowded together like drift, while in other places the strata have been only cracked and somewhat plicated. A similar case of fracture, without the removal of the fragments much out of place, may be seen in a quarry at the north end of Mount Tom, in Massachusetts.

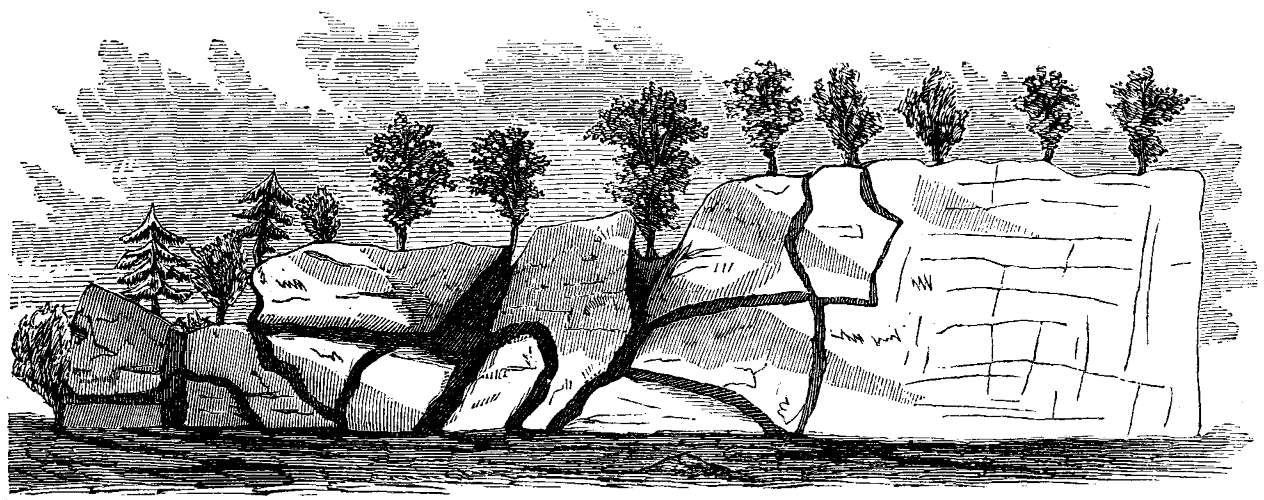
One of us, in 1850, found in the famous slate quarries of Llanberis, in North Wales, that the laminæ had been broken and bent down just as in Guilford and Dummerston, although on a less scale in Wales. Mr. Darwin and other English geologists have described similar cases elsewhere.

Here, then, we have a wide-spread effect indicative of a common cause, or causes. Thirty years ago, when only the case at Guilford was known to us, we shrunk from assigning any cause. But twenty years ago, when the facts were multiplied, we regarded the phenomena as the result of thick masses of ice resting upon the surface, and subject to a horizontal movement. Either glaciers, or ice islands and icebergs, would answer the conditions of such an agent, though where the force seems to have operated in different directions in the same region, the ice island and the berg would most satisfactorily explain the effects. Charles Darwin supposed that the bergs might have been lifted up by the waves and then brought down upon the ledges like a vast maul. But great weight and a powerful horizontal (onward or lateral) strain would be all that is necessary, and much better explain such cases as those at Rutland, Newark, and Niagara, than Darwin's gigantic battering ram.

On visiting Bruce's quarry a few years ago, in the spring, we found unmistakable proof that frost, getting between the layers of slate, and snow by its weight, had opened and bent them down more or less, and for a time we were inclined to suppose that such might have been the origin of the whole disturbance, which we believe was the theory ultimately adopted by Dr. C. T. Jackson. But this cause is quite inadequate to explain such a case as we have sketched above (Fig. 35) in Dummerston, and still more so to account for the enormous downward pressure which at Willard's quarry in Guilford and in Newbury has thrown the strata to the depth of twenty feet into a zigzag form, or even crumpled them together, and it applies not at all to the cases at Rutland, Newark, Niagara, and Northampton. Our final conclusion, therefore is, that the strata were first crushed and dislocated by huge masses of ice, probably during the drift period, or in some cases even earlier, while yet the layers retained some degree of plasticity, and that even up to the present time frost and gravity have been carrying on the work of loosening and urging downwards the fragments.

In the northeast part of Pittsford, an interesting example of ledges broken up by some powerful agency, was pointed out to us by B. F. Winslow, Esq., of that place. It is on the east side of Furnace River, say a mile or so northeast of the Iron Works on that stream, a little east of the road leading to North Chittenden. The north end of a hill, or mountain, called, we think, East Peak, is here exposed; so that either water or ice coming from the north, or northeast, down Furnace River, would strike with full force against this projection of the mountain. A few hundred feet above the stream, a little higher than the modified drift rises, several ledges are laid bare, concerning which one doubts at first whether they be rocks in place, or enormous bowlders, piled upon one another. Examination discovers both bowlders and ledges. Those most northerly are distinct bowlders, often of gigantic size. But proceeding southerly, although the surfaces exposed are embossed, yet from their size we begin to doubt whether they are not bosses of the ledge: and a little farther we reach distinct ledges. We become satisfied at length, that some powerful agency has impinged against this hill from the north, tearing up the rock as far as it was able, but not able to remove the whole hill. The rock is an aggregate of mica and quartz, almost entirely destitute of stratification or foliation, and is probably a metamorphosed sandstone, having the aspect of a dark-colored granite. It would stand a crushing agency as well as any rock we have ever seen. We give in Fig. 38 an imperfect sketch of the lower and most disturbed portions of these ledges, as we look upon them from a station where we can see the bowlders on the left and the solid ledges on the right.

Fig. 38.



The drift agency from the north or northwest, might have done this work. But the inquiry was excited, whether a glacier did not once descend Furnace River. If so, it would explain the phenomena equally well. We regret that want of time prevented us from searching for traces of a glacier along the river.

THE ICEBERG THEORY OF DRIFT.

It may be well to pause here to point out the leading features of the manner in which drift and its subsequent modifications have been produced, according to the views which we have been led to adopt. All geologists we believe consider ice and water to have been

the agents, and they differ only in the proportion and manner in which they have operated. One class consider the whole country to have been overspread for a long time with a sheet of ice of great thickness, in the form of a glacier, which urged its way southerly, scoring the rocks and transporting the bowlders. The access of heat to melt the glacier produced abundant currents of water, by which deposits of finer materials were made upon the drift, or sometimes in the midst of it.

We are unable to adopt these views; first, because all known glaciers are confined to valleys, though at their head they may be connected with extensive fields of ice, capping the summits of the mountains: secondly, because no known glacier is more than 50 or 60 miles wide (the great glacier called Humboldt, in Greenland, described by Dr. Kane, is of this width), whereas the ancient American glacier must have been at least 2500 miles wide, and have spread over all the mountains as well as valleys, and often have been obliged to move up hill as well as over a level surface: thirdly, because in our country we have two and probably three prominent directions to our drift, and it is difficult to see how one glacier would have moved in so many directions, especially as the most usual course of the striæ in New England does not follow a valley, but crosses over mountains obliquely.

We have no doubt, however, that a part of what we call drift phenomena in New England was produced by glaciers, such as we have described as once connected with the Green Mountain range. But the main features of drift we impute to icebergs and icefloes, as the continent was gradually sinking beneath the ocean. All will admit that it was depressed 500 or 600 feet, as late as the drift period, because to that height we find in Champlain valley and in Canada sea shells in the regular deposits, and we shall endeavor to show that we have other evidence that it went down 2000 feet, or more than sufficient in fact to bring icebergs over the tops of most of our mountains. Their effects, in connection with that of shore ice on the rocks at the bottom of the ocean, could not be distinguished from those of glaciers, both having gravel and bowlders frozen into their under side to act as gravers. Some icebergs in the Atlantic have been seen that extended 2500 feet below the surface, deep enough to reach the bottom anywhere, if we suppose the ocean to have risen 2000 feet above its present level. Moreover, such a depression of the continent would bring a northerly or northwesterly oceanic current over it, which would bear along icebergs and icefloes, as is now done in the Atlantic. These would depress the temperature so that glaciers might form on the mountains as they rose out of the ocean.

Two circumstances make it probable that the main features of drift were produced by a sinking rather than a rising continent: One is, that in this way we can explain the occurrence of striæ on the stoss side of mountains, running up hill. For, suppose an iceberg to strand on the northern side of a hill which was sinking;—as the hill went down, however slowly, the iceberg would be urged by the southerly current behind it higher and higher up its side, and at length over it, pressing hard upon the ledges beneath and scoring the surface. The other circumstance is, that many of the phenomena of modified drift indicate that most of this was deposited while yet the continent was beneath the ocean, and that the valleys formed in it were the result of drainage, which implies an elevation of the land. In many cases we can show that old river beds were filled by modified drift during the sojourn of the continent beneath the ocean, and if so it must have been done before the land had risen much. Hence the denudation of the surface and the accumulation of the unmodified drift must have been an earlier work. It was not indeed completed during the subsidence of the land, nor is it yet completed. But the period of subsidence seems to have been the time when the work was carried on with the greatest energy.

We regard the drift agency, then, to have been mainly icebergs, icefloes, and shore ice, while the country was sinking beneath an ocean made arctic by currents from an arctic sea—a state of things mainly such as now exists in high latitudes. To these were added the effects of glaciers, which under such circumstances must have existed. Mountain slides, waves of translation, and the ice of rivers, might also have aided in the work.

Now the same agencies continued to operate, modified indeed and with less intensity, while the continent was rising out of the waters; and we find the results in what we call Modified Drift. For we suppose that the ice and water would now act mainly upon the drift already accumulated, reducing it into finer portions, sorting the materials according to the strength of the current, and re-depositing them as stratified masses in the form of Beaches, Sea Bottoms, and Terraces. These all lie above the drift, and must have resulted from subsequent operations. It is impossible, however, to say where drift proper ends and modified drift begins. Indeed, after the latter in some cases had been accumulated to considerable depth in the form of sand and gravel, there is evidence, in the large bowlders lying occasionally on their surface, that icebergs continued their work of transportation. Yet gradually the erosive agents became less powerful, and the materials deposited finer, until in our day the almost impalpable powder of alluvial meadows shows us how altered and diminished is the drift agency; though existing glaciers make a much nearer approach to their ancient power.

We adopt the theory, then, that the gradual drainage of the country as it rose out of the ocean by almost imperceptible increments, or as the waters retired while the continent stood still, which hypothesis has certainly strong arguments in its favor. At first, only a few of the highest mountains would project, as islands above the waters. But the waves and currents would begin their action upon the shores and the bottom, and the materials worn off and comminuted would be arranged in the form of beaches or sea-bottoms. But not till a considerable part of the land had emerged, and chains of lakes were produced, and incipient rivers formed currents through them, would regular terraces begin to be deposited. But the modes in which these and other forms of modified drift have been produced, will require numerous details in order to be made intelligible, and as it is a branch of geology comparatively new, we allow one of our number, who has made this department of the geology of Vermont an object of special study, to occupy a good deal of space in describing the phenomena as they occur in the State, and in drawing general conclusions. It is a branch of the survey, however, that has been more imperfectly attended to than any other perhaps,—as none of us have felt authorized, with the limited means at our command, to give much attention to surface geology, except in connection with the study of the older rocks. Yet we cannot doubt that the facts will awaken a deep interest in every one who sees what remarkable changes they indicate in the surface.

PHENOMENA OF MODIFIED DRIFT.

TERRACES AND BEACHES.

BY C. H. HITCHCOCK.

Terraces are objects of common observation. The inhabitants of the Green Mountain valleys, and the travelers who visit the different parts of the State for business or pleasure, are equally struck with admiration of their number, form and symmetry. And it is with peculiar pleasure that we discuss their relations and origin, because we shall not speak of what is unseen or unknown. We are not obliged to dig into the earth to find them, nor will our reasonings upon their formation be so abstruse that they cannot be understood. Whoever will observe their order in nature will not fail to appreciate reasonable theories respecting their origin.

Though valleys are so very common, people are not apt to inquire how they were formed, nor why their sides are lined with terraces; but they make a practical use of these beautiful situations furnished by nature as sites for their pleasure grounds, dwellings, villages, and cemeteries. Very few persons have thought how much indebted to terraces for their beauty are the towns of Brattleboro, Newbury, and Waterbury. Among the many villages in the State besides these, whose natural attraction is in a great measure caused by these terraces, are Vernon, Westminster, Bellows Falls, Weathersfield, Windsor, North Hartland, White River Junction, Bradford, Wells River, Guildhall, and Canaan, upon Connecticut River; Fayetteville, upon West River; Proctorsville, Cavendish, and Ludlow, upon Black River; Quechee Village and Woodstock, upon the Otta Quechee River; White River Village, Bethel and Randolph, upon White River; St. Johnsbury Plain and Lyndon, upon Passumpsic River; East Bennington, upon the Waloomsac River; Pawlet, upon Pawlet River; Poultney, upon Poultney River; Brandon and Pittsford, upon Otter Creek; Burlington and Richmond, upon Winooski River; Milton Falls, Johnson and Hyde Park, upon the La Moille; besides others perhaps upon the Missisco River, which we have not had sufficient opportunity to examine. Of cemeteries built upon terraces, we remember to have noticed those at Windsor and St. Johnsbury as particularly attractive. To mention particular dwellings or pleasure grounds, whose attractiveness arises substantially from their terraced site, would exceed our limits,—suffice it to say that along the principal rivers they are very numerous and attractive.

Though terraces are so numerous and striking, yet geologists have not devoted much attention to them. In their endeavors to discover the relations and contents of the lower and more hidden formations, they have neglected the superficial layers. Hence there is some diversity of opinion among geologists respecting both the facts and theories relating to surface phenomena. The fullest works on terraces and old sea beaches, are Charles Darwin's *Geological Observations upon South America*, published in 1846; Robert Chambers' *Ancient Sea Margins*, published in 1847, and a Memoir in the ninth volume of the *Smithsonian Contributions to Knowledge*, published in 1857, entitled *Illustrations of Surface Geology*,* by Edward Hitchcock. The views presented in this last work, arrived at, as

* In 1860, J. S. & C. Adams, of Amherst, Mass., published a second edition of this work, which contains a few descriptions not found in the first edition.

they were, after careful study and protracted investigation, will be in general adopted in this Report. In the memoir referred to, facts are presented from Europe, Asia and Africa, as well as from the United States, from which to draw conclusions. So in drawing our conclusions in the present Report respecting the formation of terraces and sea beaches, we may be constrained to infer from phenomena not noticed in Vermont, or else existing under forms scarcely recognizable, when considered by themselves alone. Still, the most prominent objects worthy of notice in our discussion are found in Vermont, and will be given in detail in the following pages.

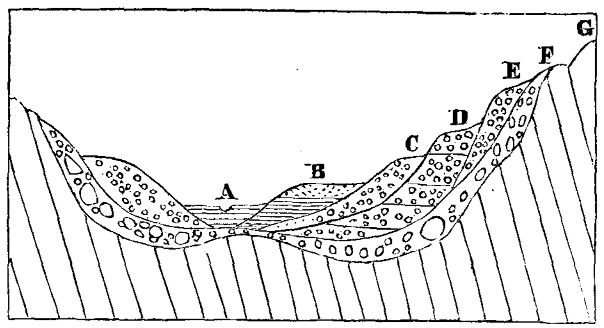
The term *terrace* applies to any level-topped surface with a steep escarpment, whether it be solid rock or loose materials. We apply the term, when treating of surface geology, only to those banks of loose materials, generally unconsolidated, which skirt the edges of the valleys about rivers, ponds and lakes, and rise above each other like the seats of an amphitheater. There is no danger of confounding the alluvial terraces (of which alone we speak) with terraces of the tertiary period, unless it be a mongrel terrace of the later tertiary, found along the west base of the Green Mountains. This will be treated of under *tertiary rocks*.

GENERAL LITHOLOGICAL CHARACTER AND RELATIVE SITUATION OF THE TERRACES AND BEACHES.

In general, the following description is applicable to the terraces and ancient beaches:

1. The most perfect terrace is an alluvial meadow, annually more or less overflowed and increased by a deposit of mud or sand. Except in rough mountain streams the materials are rarely as coarse as pebbles over an extensive surface, and they are distinctly stratified. (See A on Fig. 39, which is an ideal section across a terraced valley.)

Fig. 39.



Ideal Section of a Terraced Valley.

2. Ascending to a second terrace, we almost invariably find it composed of coarser materials. In the section, it is represented (Fig. 39, B) as composed of clay beneath and sand or fine gravel above. This is an arrangement common to the greater part of the second and third terraces throughout Vermont and New England, though sometimes the sand is wanting.

3. The third terrace, or the next above the clay and sand terrace, is usually a mixture of sand and gravel; the latter not very coarse, the whole imperfectly stratified, and also sorted; that is, the fragments in each layer have nearly the same size; as if the waters that removed and deposited the materials, had a different transporting power for each stratum. (C, Fig. 39.)

4. The fourth terrace or the highest, D in Fig. 39, differs from the last by its coarser materials and more irregular surface. As we ascend the terraces from the river, we find the character of each less distinct. For the highest terraces were first formed, then the next lowest in succession. Hence rains and freshets have acted the most upon the upper terraces, and have caused these irregularities. Indeed the lower terraces

are generally composed of the ruins of the higher terraces, modified, rounded and assorted by currents of water.

But there are often elevations and depressions in the highest terrace of a different character from the gullies and ravines excavated by rains and freshets, which seem to have constituted the original surface of the terrace. They may be described as rounded or curved elevations, with similar depressions; which have been likened to a *chopped sea*, or to the eminences and anfractuosities on the surface of the human brain. These elevations and cavities could not have been made by water alone, for the depressions are basin-shaped, and vary from ten to one hundred feet in depth, while the unbroken margins forbid the idea of the previous exit of any current from the depressions. Yet the materials are often stratified and always water-worn. No level-topped terrace is ever found above this terrace. These deposits are called *moraine terraces*. They form an interesting feature in the scenery of valleys, and are among the most difficult of all the phenomena of Surface Geology to sketch satisfactorily. They will be referred to again, inasmuch as similar phenomena are found away from rivers upon elevated plains and valleys. Their place in valleys is shown in D, Fig. 39.

5. Above the terraces, in our ascent from the river, we find other accumulations of decidedly water-worn materials, generally coarser, the fragments of rolled and smoothed rock being sometimes a foot or two in diameter, yet still more or less sorted. Coarse sand, however, constitutes the greater part of the deposit, and sometimes the whole of it. Its outline is rounded, rarely with a level top for any considerable thickness. Yet in its longest direction it maintains essentially the same level, and often may be seen for many miles at the same height, as a sort of fringe along the sides of the hills that bound a valley, appearing as if these deposits once formed the beaches or shores of estuaries that occupied those valleys. Such they are supposed to be, and are what will be described as *Ancient Sea Beaches*. One is represented in the figure (E, Fig. 39) as skirting the side of the valley near its border, and not extending far beneath the terraces, as it was formed upon a shore. As we rise still higher, the materials are less rounded, and may have formed beaches at higher levels, when less opportunity was afforded to the waters of wearing away and comminuting the rocks.

6. Passing beyond and above the terraces and beaches, thus lying at the bottom, and along the sides of the valleys, we reach the genuine drift deposit (F, Fig. 39), consisting of materials that are coarser, more angular, and less arranged in strata. These are strewn promiscuously over the hills, except those quite steep, where the materials could not find a resting place. They are also seen occasionally in the valleys, wherever the terraces and beaches have been worn away or never existed. Yet it must be confessed that it is often impossible to draw a line of distinction between the oldest beaches and the drift. They pass insensibly the one into the other. The large blocks of the drift are indeed frequently angular, but they are mixed with finer materials that have been ground down and rounded, either by aqueous or glacial agency; and the oldest beaches seem to be of essentially the same materials, somewhat more modified.

It is important, also, to mention that what appears to be genuine drift is sometimes mixed with, and sometimes superimposed upon, the beach and terrace materials. This is especially true of large erratic blocks. And it shows us that the drift agency, whatever it was, occurred in some places after the modifying agency that formed the older beaches and terraces had been for a time in operation. Or, more probably, it was the same agency in modified forms that produced all the phenomena. The ideal section which we have referred to shows also the superposition of the different stratified beds. First and oldest are the strata of solid rock, which are unconformable to the alluvium. The drift underlies all the terraces, and the highest terraces run under the lower ones. Hence the paradoxical fact that the highest deposits are older than the lowest. This section also shows what is the common state of things in regard to the relative number of terraces upon the two sides of a valley. Some have stated that the terraces on both sides are the same in number, and at the same level. Here both the number and the height above the river are different upon the two sides; and this illustration corresponds to the general arrangement in Vermont; for this ideal section conveys the general impression made on the mind by all the cases that have been examined.

River terraces are generally arranged in basins, which vary in length with the rate of descent of the bottom of the valley. Where a river descends so slowly as to appear slugggish and muddy, a basin may extend for many miles; but in rapid streams the basins are more frequent, and are often at different levels. At the ends of the basins the solid rock generally forms the banks of the river and always approaches near the water.

ORIGIN OF THE MATERIALS.

1. It has already been stated that beaches and terraces appear to be modified drift.—The agency by which the first was produced, commenced the process of separation and comminution, carrying it at first only far enough to form the higher and coarser beaches. The work still went on with another portion, till it was reduced into finer materials for the higher terraces,—and still finer for the lower terraces, until when it came to the lowest of all—our present alluvial meadows—the fragments had been brought into almost impalpable powder, so as to form fine loam.

2. Such a work could not go forward with fragments already detached from the ledges, as was drift, without subjecting the solid rocks to erosion wherever exposed. Accordingly a part of the materials of the terraces and beaches must have been derived from this source. How deep in any place these erosions have been made, may be learned by ascertaining how near the bed of the stream we find drift striæ. Reasoning in this way we find upon the La Moille River, for instance, that at East Fairfax the rock has been scarcely denuded since the drift period, as the striæ are within five feet of the water's edge; while at Wolcott, on the same stream, pot-holes have been found fifty feet above the water's level. In other places rock to the amount of 200 to 300 feet has been eroded.

ARRANGEMENT OF THE MATERIALS.

1. *Stratification and Lamination.* All these deposits are more or less stratified, and most of the finer varieties are also laminated. The lamination is not unfrequently oblique to the stratification. The former is frequently inclined as much as twenty degrees to the horizon, the latter usually quite horizontal, though the strata or laminæ of clay are sometimes plicated.

Sometimes there is a structure like cleavage present. Fig. 40 represents a section in a terrace at Bartonsville (Rockingham.) It is represented as Terrace No. 4 upon the map of the Surface Geology, Plate II., and upon Plate VII., Fig. 1, where an enlarged map of some terraces upon Williams River is given. Its place is easily found on these maps by noticing the point where this terrace curves and crosses the valley. By an excavation made for the Rutland and Burlington railroad, and by the action of a powerful freshet recently, a large part of the terrace was worn out, leaving cliffs of clayey sand exposed on either side. It is from the cliff upon the east side of the railroad track that this figure is taken.* A A represent two strata, each about three inches in thickness, composed of numerous laminæ. *a a a a* B represents a stratum six inches in thickness, composed of laminæ, *a a*, like A A. In addition to these lines, the action of the weather has brought to light another system of planes *b b*, dipping at an angle of fifteen degrees to the north. They protrude from the surface of the cliff very much as segregated veins are elevated above the surrounding mass of rock upon blocks of stone where the weather or drift agencies have been at work. It is not a laminated structure, for the laminæ are horizontal; which position is very clearly shown by little scales of mica lying upon their flat surfaces, and moreover the dip is in the wrong direction to suppose them formed by deposition. The dip is to the north, while the current of deposition acted from the north to the south; and were these planes laminæ, they would dip to the south. It seems to be analogous to a cleavage structure; though it may not cleave in the direction of these planes so easily as in the direction of the planes of lamination. It would certainly lead us to inquire whether cleavage planes may not be formed withoul the aid of heat and pressure, by some simple agency in operation at the present day.

S. FIG. 46. N.

Section in a Terrace at Bartonsville.

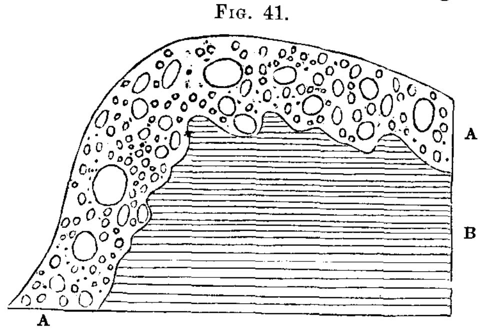
Certain deposits of the age of terraces, and in many cases forming terraces, are represented by some geologists as neither stratified nor laminated. Such a deposit is found along the valley of the Rhine, and is called *loess* by the Germans, and *limon* by the French, and upon the Mississippi River, in America, in the *bluffs*. Doubtless the stiff clays of the Champlain valley at times possess the same indistinctness, for their composition is the same as that of the loess, viz: fine calcareous clay. We have never seen a case where stratification was wholly obliterated, though it is often quite indistinct. And it should be observed here that when a deposit has been exposed to the weather, even for a short time, all traces of stratification and lamination may disappear: but when fresh excavations are made in it, both of these structures are distinct. The numerous cuts made by railroads display the structure of terraces in many cases very finely, where no trace of parallel arrangement can be discerned upon the surface. In this way stratification may be seen in beds of pebbles, apparently thrown promiscuously together.

2. *Sorting.* Wherever a section is made into a terrace, composed of clay, sand and pebbles, we see that these varieties of material are usually arranged in distinct layers, the coarser together, and the finer together. The impression is irresistible on the mind, that the water, which made the deposit at one time, had only velocity sufficient to move the finest sediment; at another, small pebbles; at another large pebbles; and sometimes to urge along masses of considerable size. In such cases the stream chose out, and carried forward the largest pebbles or blocks, which its particular velocity would raise, leaving other fragments for a time when its power should be increased. In this way have the materials been sorted out more nicely than any mechanical skill could have done.

*In 1860 this cliff was nearly gone. It will be entirely gone in two or three years hence.

Fig. 41 exhibits a section of a lateral terrace upon a small stream emptying at Williamsville, into a branch (Rock River) of West River. The thickness of the terrace is about twelve feet, and its height above the river about twenty-five feet. It is composed of sand, B, and coarse gravel, A. The sand is quite fine, and the gravel very coarse, many of the pebbles being a foot in diameter. The gravel bed is of uniform thickness — two feet — and shows no marks of stratification. Besides the sorting process, this section shows that a portion of sand has been removed previously to the deposition of the gravel, the amount of which we can only conjecture.

Fig. 41.

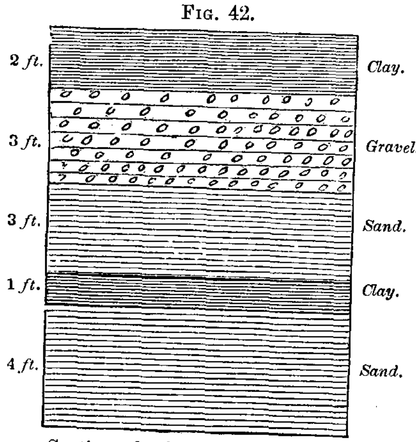


Section in a Terrace at Williamsville.

Similar sections to this are found in many parts of the State. Our note books contain sketches of some in the upper part of the valley of the Passumpsic River. There the beds of alluvial deposits are finely exhibited in the excavations made for the track of the Connecticut and Passumpsic River Railroad. Sometimes the bed A in the figure is reduced to a few inches of thickness, and then does not seem to have been deposited by water, but accumulated gradually by the mingling together of loose portions of sand with vegetable matter, thus forming a soil.

We give from Rev. S. R. Hall's Report to Prof. Adams in 1846, two sections of interesting alternations and changes of material in different strata. They are sections of terraces.

Fig. 42.

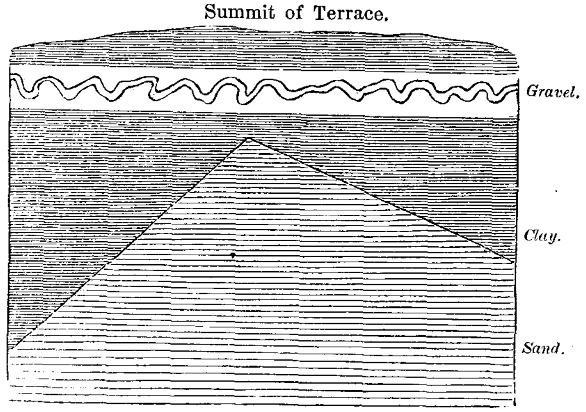


Section of a Terrace at Bethel.

"Near the village in Bethel on White River, there *was* a hill, perhaps twenty feet high, which when I was there was being removed for constructing the railroad. The different kinds of materials are arranged as in Fig. 42, and with the thickness represented by the 2 ft., 3 ft., etc. on the left side of the figure. The third layer from the top of the sand was somewhat curved upwards, the rest were nearly horizontal. About four feet of the lowest layer of sand were exposed, and the sand extended deeper still into the earth. The summit of the hill where nearly level, contained several square rods of surface.

"A still more irregular arrangement of clay, sand and gravel is seen, where a cut is made for the railroad at Windsor, on the south side of the 'Hour-Glass'. The great proportion of this hill is loose gravel and river deposits, as seen where the stream has washed away the south side of the hill. On the south side of the hill, half a mile distant, the material is principally clay, or clayey sand. Fig. 43 represents a perpendicular section of that part of the hill left on the east side of the excavation. From the top is a steep descent to the river, some 150 feet below. The very crooked line (zig zag) near the top represents a narrow stratum of gravel in the clay, nearly horizontal in its general direction but exceedingly contorted when traced specifically.

Fig. 43.
Summit of Terrace.



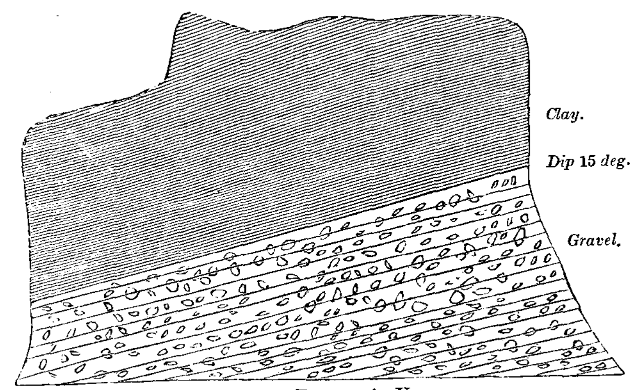
Section of a Terrace in Windsor.

"The height of the section is twenty feet. The clay appears to have been deposited upon the sand in still water, after the sand had been accumulated and partially worn away. The clay is horizontally stratified, as well as the sand.

"At St. Johnsbury, half a mile south of the plain, is a bank where a narrow stratum of clay rests on sand. Above the clay is a deposit of gravel, several feet thick.

"From Hon. William C. Bradley, of Westminister, I learned, that on penetrating the loam, on the extensive plain (terrace) in Westminster, a thick bed of gravel is found, and beneath the gravel a stratum of blue clay, two or three feet thick, and beneath this is quicksand.

Fig. 44.



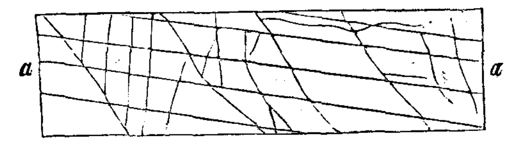
Section of a Terrace in Vernon.

"Dea. Gray of Coventry informed me, that after penetrating the loam and hard pan 40 feet, on his farm, he struck a bed of very tough blue clay, six inches thick, and that this rested on quicksand.— His well yielded an abundant supply of water for a few years, when it suddenly disappeared, and remained dry ever after, till it was filled up."

Fig. 44 represents an insulated hill of gravel and clay, five rods long, in Vernon, near the meeting house. It is on Connecticut River, and is doubtless one of its terraces. It is not usual to find so great a dip in strata of clay and gravel.

We were much surprised to discover in strata of sand in North Dorset, a large number of *segregated veins*. The locality is nearly a mile south of the railroad station, upon the east side of the carriage road to Manchester. An excavation has been made in one of the large piles of detritus filling the valley in the manner of a gorge terrace, by the removal of the fine sand for economical purposes. In 1859 this excavation was three rods long and about forty feet high. Fig. 45 gives some idea of the appearance of the veins intersecting the strata, over a part of the excavation. The strata dip five degrees to the southwest, while crossing them at various angles are the segregated veins.

Fig. 45.



We measured veins inclining southerly both 46° and 22°. Some are nearly perpendicular, and rarely some are approximately horizontal. There were an immense number of very small veins, not represented in the figure, which branched in every direction, and were often anastomosed. The veins were made conspicuous by their elevation above the surface of the surrounding sand, precisely as segregated veins now appear in metamorphic rocks. Were it not that they are harder than the materials in which they ramify, their existence might not be suspected.

These veins must have been superinduced after the deposition of the sand — for there has been no mechanical disturbance, and the materials of the veins does not differ appreciably from the sand in the strata. For their origin we must perhaps look to the same agencies which have produced segregated veins in the older rocks, i. e., chemical or galvanic action. We can conceive of no other possible agency to have produced these sand veins in North Dorset.

We fear that this exhibition will not long show itself to visitors; for only one year after it was discovered, we visited it the second time, and found many of its features obliterated. Nature and artificial excavation both conspire to produce this result.

MODE OF REPRESENTING THE TERRACES AND BEACHES UPON MAPS.

Upon the general map of the Surface Geology of Vermont, Plate II., we have attempted to exhibit the principal terraces by means of colors. Many smaller ones, however, are omitted; nor is the true width of the terraces given with great accuracy. The map is so small, that the surface which a terrace covers would not generally be large enough to represent the terrace at all; hence the width on the map is exaggerated, except where the terrace is very large. To give these phenomena with absolute accuracy, would require a great amount of labor in observation, which would be useless unless the details could be represented upon a map—say twelve feet long for the whole State—and the Legislature would hardly think the value of the map sufficiently great to incur the expenses of its publication. Nevertheless, though an exaggerated scale may be generally used, the proportions of the terraces to one another are preserved, as nearly as possible; and the proportional variations in width, &c. on the map, are truly delineated. Besides general map we have given several local maps of the terraces, &c. These, being projected upon a larger scale, may be regarded as correct representations. We would gladly have enlarged the number of these local maps,—not only from their great value to science, but also for the use of the inhabitants of the various villages, where the phenomena of surface geology are developed.

All the streams, it will be observed, are not marked with terraces. This is because we have not had opportunity to visit them all for this purpose. The principal deficiency is on the Missisco River; but the loss is partly compensated by the fact that the terraces are not as strikingly developed there as elsewhere. The map of the surface geology of Connecticut River, upon Plate III., is perhaps the most valuable contribution to science of the whole. It was reduced from a large map over thirteen feet long.

We are now able to map the terraces from the mouth to the source of Connecticut River, by combining with Plate III. of Hitchcock's *Illustrations of Surface Geology*. This is the first time, we believe, Plate III. in the history of Geology, that the alluvial deposits of so large a river have been as fully delineated. We did not represent the Surface Geology of Connecticut River upon Plate II., because it would have been a useless repetition of Plate III. We have the materials for similar maps of the Winooski and Lamoille Rivers, besides some of the larger tributaries of the Connecticut, but they are not engraved because of the expense.

The colors on all the maps are the same for the same terraces, reckoning upward from the river. The lowest meadow is considered the first terrace, the next higher the second, and so on; hence it follows that the same color does not always represent terraces of the same height, since they vary in this respect on different streams; and in general, the size and height of the terrace correspond to the size and height of the river.

In all the references to the terraces in this report, we shall designate them as No. 1, No. 2, &c., counting them at every place where the largest number is found to occur. Sometimes several terraces, especially those designated as No. 2 and No. 3, are wanting when we say that Nos. 1 and 4 are present at this particular locality, because the terrace called No. 4, a mile distant, continues unbroken to this spot, while the others have been worn away. While we cannot represent the terraces of the same height, upon different streams, by the same color, we endeavor to represent the terraces of the same height upon their own stream with the same color, so far as an equable height is maintained by the terrace itself—which is not always the case.

Upon a few streams that descend rapidly, what we shall presently designate as the Lateral and Delta terraces, are rarely partially combined—as upon the Whetstone Brook that empties into the Connecticut River, in the village of Brattleboro. A similar very marked case is described in the *Illustrations of Surface Geology*, and figured upon one of its plates (Plate VI., Fig. 2.) It is stated that in Pelham, Mass., upon Fort River, there are thirteen terraces, each one higher than the preceding, but the thirteenth is no higher above the river opposite to it than the fourth opposite to the same stream. If, then, we should estimate the terraces upon Whetstone Brook by calling every one that is found at a higher *absolute* level an additional one, we might run up to twelve or fourteen, while the fourteenth above Connecticut River would really be the fourth above the brook in West Brattleboro.

The beaches are represented by two colors—one for the Champlain clays which include some of the lower beaches, and another for the more elevated gravel and sand beds which as yet have afforded no marine relics. No distinction is attempted to be made between the higher and lower beaches of the latter character, though their difference of level is quite great at some localities.

Modified Drift is embraced under six forms: River Terraces, Lake Terraces, Maritime Terraces, Moraine Terraces, Beaches and Sea Bottoms.

I. RIVER TERRACES.

These are the most perfect of all, and are found along the shores of almost all rivers, but especially those passing through hilly countries, and forming narrow basins with a succession of gorges. River terraces may be subdivided into four varieties, differing in position, and probably, also, in their mode of formation.

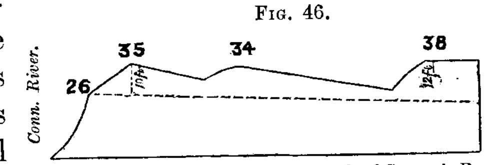
1. *The Lateral Terrace.* This is the ordinary terrace which we meet along the banks of a river, often many miles in length, and sometimes even miles in width.

2. *The Delta Terrace.* This occurs at the mouths of tributary streams, and was most obviously a delta of the tributary, but as the waters sunk, the delta was left dry, and the tributary cut a passage through it, so as to form a terrace of equal height on opposite banks.

3. *The Gorge Terrace.* This occurs either above or below the gorges of a stream, and is intermediate between the lateral and delta terraces, graduating into both.

4. *The Glacis Terrace.* This is not level-topped, but slopes gradually both ways from its axes—on the side next the stream much more rapidly than on the other. Outwardly it resembles the *glacis* of a fortification, and hence the name. It is usually found in alluvial meadows, and might perhaps be regarded as merely the uneven surface of a lateral terrace, as it is seldom more than a few feet high. The true types of the glacis terrace are found in South America, as described by Charles Darwin, and among the Alps, where broad terraces slope very rapidly towards the stream to its very brink. Fig. 46 represents one of the best examples of this kind of terrace found in Vermont. The sketch is taken from the *Illustrations of Surface Geology*, Plate II., No. 31, and the originals are found near the mouth of Saxton's River, just below Bellows Falls. They are laid down accurately—the heights above Connecticut River, respectively, 35 feet and 34 feet; their thickness, respectively, 10 feet and 12 feet; and their length, respectively, 14 rods and 16 rods,—all being given as determined by leveling. On Fig. 54 they may be seen in their relations to a much larger section crossing the valley. It will be seen that they constitute merely undulating portions of the lowest terrace, and perhaps ought not to be considered as distinct terraces. Yet they are sometimes of considerable height, and deserve notice, because they show us one of the modes in which nature accumulates terrace materials. The method of their formation will be considered elsewhere.

FIG. 46.



Section of Glacis Terraces near mouth of Saxton's R.

II. LAKE TERRACES.

These scarcely differ from the lateral terraces of rivers. Indeed, many small lakes, and even some of the larger ones, appear to have been merely expansions of rivers, such as are now seen in great numbers in the basin of the upper Mississippi, west and southwest of Lake Superior. In Vermont, the map of Washington county shows an example in a branch of the Winooski River, called Kingsbury Branch, uniting with the Winooski at Montpelier. If we follow up Kingsbury Branch to Sabin Pond, in Woodbury, and then pass up the left hand stream from this to its source, we shall pass through eight ponds. We have only seen the most southern of these ponds, so that we cannot certainly say that they are all surrounded with terraces: but feel confident in saying that when the water in them shall have disappeared, terraces will be found in the beds that are left behind.—Counting all the ponds that feed this branch, they amount to more than thirty. The terraces which surround lakes and ponds, indicate the former different levels at which the water stood in them.

III. MARITIME TERRACES.

Perhaps we ought not to regard the accumulations of gravel and sand upon the sea shore as terraces, but beaches. A few of them, however, are so nearly level-topped as not to differ from genuine terraces, and this is the main distinction between terraces and beaches. It is not, however, a distinction of much practical importance. At the mouths of rivers the two varieties are often seen running into each other.

IV. MORAINE TERRACES.

This term is applied to a peculiar form, already spoken of, not unfrequently assumed by the more elevated terraces, exhibiting great irregularity of surface, elevations of gravel and sand, with correspondent depressions of most singular and scarcely describable forms. The term *moraine* is prefixed to terrace, under the impression that stranded ice, as well as water, was concerned in their production. It also embraces those alluvions that frequently occur on the height of land between the sources of streams flowing in opposite directions.

V. SEA BEACHES.

The most perfect of these are seen along the sea coast in the course of formation. They consist of sand and gravel, which are acted upon, rounded, and comminuted by the waves, and thrown up into the form of low ridges, with more or less appearance of stratification or lamination. As we rise above the terraces along our rivers, and often on the sides of our mountains, we find accumulations of a similar kind, evidently once deposited by water and having the form of modern beaches, except that they have frequently been much mutilated, by the action of water and atmospheric agencies, since their deposition. These have hitherto been confounded with drift, but they always lie above it, and show more evidently the effects of some comminuting, rounding, and sorting agency — of water, indeed, since this is the only agent that could produce such effects. They evidently belong to a period subsequent to the drift, and we cannot doubt that they once constituted the beaches of a retiring ocean. The proof of this will be given further on.

We have spoken of these beaches as lying above the terraces. We mean that they are at a higher level often, but geologically they are lower. When terraces occur as well as beaches, the latter always are seen at a higher level than the former; usually forming fringes along the sides of mountains. Yet in other places rivers may exist at a much

higher level, which have terraces also; and usually above them we find beaches, still retaining the same relative position to the terraces.

VI. SEA BOTTOMS.

The bottom of the present ocean, along the coast, is in many places covered by deposits of sand and gravel, left there seemingly by tidal action, and presenting often numerous ridges and depressions. Often, too, bars are formed across the mouth of harbors, producing lagoons. Hooks, also, are produced, where the currents sweep around headlands. While these deposits are beneath the waters, they go by the name of shoals. If these shoals, bays and harbors be raised out of the ocean, although they will be exposed to the modifying influence of rivers and rains, their essential characteristics will be long preserved. They are abundant in Vermont, in the great valleys that cross the State from north to south; being found at heights varying from 150 to 1500 feet above the ocean; and the lower beds contain marine fossils, of such animals as now live at great depths in salt water.

DETAIL OF THE FACTS.

Nearly all the information, respecting the terraces and beaches, has been obtained during the progress of the survey, and that without interfering with the study of the older rocks. It has been a pastime, rather than a laborious undertaking.—Unfortunately our time did not permit us to take such careful measurements of their heights as we could have desired. There was no room, amidst the great number of instruments and amount of luggage and specimens to be transported in our carriage, for carrying leveling instruments, and the Aneroid was not so accurate as we desired. Yet a few sections of terraces were measured with this instrument for want of something better; and the facts thus ascertained, with others detailed in the *Illustrations of Surface Geology*, have enabled us to give satisfactory generalizations upon the height and origin of terraces. We can thus present the principal facts of the science of terraces, leaving the additional observations and admeasurements to future observers.

We will give the details in succession upon the terraces and basins of the five largest rivers in the State, in order, commencing with the Connecticut and its tributaries, which water more than two-fifths of the State; and then taking Otter Creek, Winooski River, Lamoille River, and the Missisco River, which together water more than the other two-fifths of the state. The remaining fifth will be properly noticed also. In all these streams the terraces occur in basins, sometimes quite numerous, which we will attempt to describe in order, beginning at the mouths of the rivers and proceeding to their sources.

These basins may be connected by their highest terraces, or be separated by ridges, through which gorges have been cut and deepened by the river alone, or with the aid of the ocean. Formerly the spaces occupied by these basins must have been occupied by narrow lakes or ponds. After finishing the River Terraces we shall next *discuss* all the facts respecting Lake Terraces, Maritime Terraces, Moraine Terraces, Ancient Sea Beaches and Ancient Sea Bottoms.

BASINS IN THE CONNECTICUT RIVER VALLEY.

From the map of this valley, given in the *Illustrations of Surface Geology* and in Plate III. of this Report, we are able to enumerate at least twenty-two basins, which are the following :

1. From Long Island Sound to Middletown, Connecticut. From the mouth of the river to the south part of Haddam, Ct., twelve miles, the terraces are numerous. The remaining thirteen miles to Middletown exhibit very few phenomena of Surface Geology.

2. At Middletown the longest and widest of all the basins commences, and extends to Mt. Holyoke, where a range of greenstone crosses the valley, and separates this from the succeeding basin. It is fifty-three miles long, and from three to ten miles in width.

3. The third basin extends from Mt. Holyoke to Mt. Mettawampe in Sunderland, and Mt. Sugar Loaf in Deerfield, with an arm one hundred and ten miles long running down to New Haven, west of the principal Greenstone range, connecting Mt. Holyoke and East and West Rock in New Haven. The main basin is fifteen miles long. Another arm runs to Northfield, west of a greenstone and sandstone range of hills.

4. The fourth basin extends from Mt. Mettawampe to the mouth of Miller's River, in the northeast part of Montague, Mass. It is narrow, and not more than eight or ten miles long.

5. The next basin reaches from the mouth of Miller's River to Brattleboro, Vt. Some of its higher terraces extend across the barrier into basin No. 4, and also into basin No. 3, in Bernardston, Mass. Though seventeen miles long, it is narrow.

6. The next basin extends to Bellows Falls, a distance of seventeen miles. Near Brattleboro the basin is quite narrow ; and the terraces are best developed upon the upper five miles of the basin, north of Westminster village.

7. The seventh basin extends from Bellows Falls to North Charlestown, N. H., and Springfield, Vt., fourteen miles, where the mountains close in upon the river. Yet some of the highest terraces, at both extremities, pass over into the adjoining basins.

8. The basin from Springfield to Mt. Ascutney is ten miles long, and its northern limit is not so well marked as some of the others, but the terraces are mostly wanting against Mt. Ascutney.

9. The limits of the basins in the Connecticut valley above Windsor are generally very well defined by rocky gorges. The ninth of the series extends from Mt. Ascutney to the south line of Norwich, a rocky gorge separating this from the preceding. It is seventeen and a half miles long.

10. This basin is embraced between the north and south lines of Norwich,—six miles. Dartmouth College is situated within this basin.

11. From the north town line of Norwich to a point half a mile north of the south line of Fairlee, a distance of seven miles, is a very distinct basin, limited by rocky gorges at both ends, and displaying some fine terraces.

12. The smallest and shortest, but not the narrowest, of all the basins is comprised in an extent of five miles, all that belongs to Vermont being comprised within the town limits of East Fairlee. The meadow is quite wide over most of the distance. The northern limit coincides nearly with the latitude of the north end of Fairlee Pond.

13. The thirteenth basin extends from the limit just mentioned to South Newbury. Its northern limit is not so marked as the boundaries of the last four or five basins. The highest terrace extends from basin No. 12 into basin No. 13. Its length is eight and a half miles.

14. This basin reaches barely into the town of Ryegate, with a length of seven miles, and contains some very fine terraces, as all who have ever visited Newbury and Wells river can testify.

15. This one extends from South Ryegate to McIndoes Falls in Barnet, a distance of eight miles.

16. For a distance of nine miles, from McIndoes Falls to Waterford, the terraces are inferior to those on the beautiful basins below, but constitute a distinct basin, and are terminated by a sort of beach or shore extending to the banks of the river on both sides.

17. The next fifteen miles to the mouth of Cat Bow Brook, at the Cat Bow, have not been examined, except the first mile, where two or three stunted terraces were found. It is safe to presume the existence of at least one basin within this space.

18. The country between the Cat Bow in Connecticut River and the north town line of Guildhall, presents a remarkably fine basin for the space of seven miles, when it is intercepted by a ridge of granite.

19. The Connecticut valley presents a very beautiful series of terraces for the next eighteen miles, along the route of the Grand Trunk Railroad, and beyond to the north line of Bloomfield, which is embraced in the nineteenth basin.

20. The twentieth basin extends from Bloomfield, north line, to the vicinity of Colebrook, N. H., over a distance of five and a half miles, when the high Mt. Monadnock of Vermont interposes a barrier, though now sufficiently worn away to permit the passage of the river.

21. The valley north of Colebrook, in the Vermont towns of Lemmington and Canaan, becomes smaller: the country is very romantic with its high mountains. Some of the terraces upon this basin are quite high. The basin is six miles long.

22. This brings us nearly to the village of Canaan, where there is a fine exhibition of terraces. We did not visit the valley of the Connecticut beyond the limits of Vermont, and therefore do not feel authorized to suppose the presence of more than one basin for the sixteen miles intervening between the northern limit of No. 21 and Connecticut Lake.

The whole length of the river is about 300 miles, and its source is 1589 feet above the ocean. We will now proceed to enumerate some of the particular facts worthy of note in each of these basins. In order to give symmetry to this treatise upon the Surface Geology of Connecticut River, we consider it necessary to state briefly the most important facts relating to the terraces found along its banks in Massachusetts and Connecticut.

BASINS ON CONNECTICUT RIVER IN CONNECTICUT AND MASSACHUSETTS.

The Connecticut River has a very small delta at its mouth above tide water. The maps show but a little jutting out of the land into Long Island Sound. The river is constantly bringing down material into the Sound, whose amount cannot be estimated accurately. Should the land rise in future a few hundred feet, it would probably show quite a large accumulation of detritus. The smallness of this delta is owing partly to the fact that the present mouth of the river has not always been the point of union between the river and the ocean. Two quite extensive beds formerly carried the waters to New Haven, Ct. ; the one commencing at Mt. Holyoke, in the third basin, and continuing to New Haven, west of the Greenstone range, and in the route of the Canal Railroad from New Haven to Northampton, Mass. Nowhere is this valley more than one hundred and thirty-four feet above the present level of the river at Northampton, and the terraces on the river near Northampton are much higher than this. The other bed is along the route of the Hartford and New Haven Railroad ; no part of which can be more than twenty or thirty feet above the present level of the Connecticut at Hartford.

The terraces on the first basin resemble beaches, and are probably formed by a combination of fluviatile and oceanic agencies. The course of the river from Middletown to Lyme—its mouth—is through metamorphic rocks, like those in Vermont, while the remainder of its course from the south line of Vermont is in a sandstone of secondary age. As the sandstone is easier to disintegrate than the metamorphic rocks, this may have been a reason why the basins in middle Connecticut and Massachusetts are so much larger than the others. Certain it is, that during the age of the sandstone and earlier alluvium, the river preferred the formation of the former to the latter for its course, for the present bed in the twenty five miles below Middletown through the older rocks exhibits a narrow valley, bounded by steep and rocky hills, with occasional small meadows or terraces. The reason why the river has often chosen a later rocky to an earlier sandy region for its course will be explained hereafter.

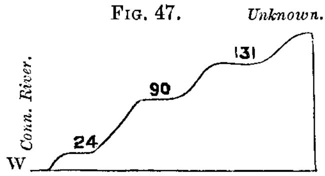
The terraces are very finely developed in the second basin from Middletown to Mt. Holyoke. The number of terraces does not usually exceed four, nor do they rise over two hundred feet above the river—the highest, a gorge terrace south of Mt. Holyoke, being 298 feet above the ocean. The upper terrace on the east side from Mt. Holyoke to East Hartford has a considerable slope to the south ; its height at various places being as follows: at Mt. Holyoke 298 feet above the ocean ; Williamansett, Mass., 268 feet ; at Springfield, Mass., and Longmeadow Mass., 200 feet ; at East Windsor, Ct., 96 feet : and at East Hartford, Ct., 61 feet.

In some places, in this basin, terrace number three is wider than the whole basin of terraces generally, in Vermont and New Hampshire. At Enfield, Ct., in this basin, the river has cut through a sandstone range of considerable height. The highest terraces, however, rise above the rocks in most places; yet, during the deposition of the lower terraces, this basin must have been divided into two of nearly equal size. The third basin—from Mt. Holyoke to Mt. Mettawampe in Massachusetts—has been the most carefully studied portion of the whole river, as the majority of the geological corps have spent the greater part of their lives in it, and are therefore better acquainted with its geology than with that of any other section of the country. The valley is eleven miles wide, and except where tributaries unite their action with the present or former channels of the Connecticut, the terraces are characterized by width rather than number. Upon Fort River, in Pelham, numerous terraces are found, formed by a combination of the two rivers—Fort river and a former bed of the Connecticut River—which are very numerous; the highest being 383 feet above the Connecticut, and 483 above the ocean. In this basin, old river beds of the Connecticut, old sea bottoms, ancient beaches of various heights, and moraine terraces are remarkably fine. Other basins upon the tributaries are very fine, especially upon Deerfield and Westfield Rivers. These, with all the details of the other basins out of Vermont, will be found clearly set forth in the *Illustrations of Surface Geology* so often alluded to. The fourth basin, though small,—from Mettawampe to Miller's River,—has many terraces, but none of special interest. The highest terrace is probably about 150 feet above the river at Turner's Falls, and forms an extensive sandy plain.

BASIN FROM THE MOUTH OF MILLER'S RIVER TO BRATTLEBORO.

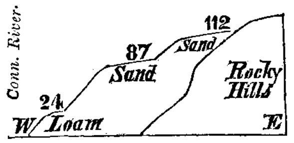
We come now to the basin which, though commencing in Massachusetts, is mostly located in Vermont. The sections in this basin, with their descriptions, are copied mostly from the *Illustrations of Surface Geology.* The heights, unless otherwise specified, were obtained by levelling. Fig. 47 represents a section of the terraces in Northfield, Mass., two miles south of the village, running eastward from Conn. River. The first terrace of twenty-four feet altitude is the alluvial meadow. The two next terraces, composed of sand, are the second and third, and are respectively ninety and one hundred and thirty-one feet above the river. The fourth terrace, or beach more properly, is irregular on its top, and was not measured.

Fig. 47.



Section in Northfield, Mass.

Fig. 48.



Section near Vt. line, in Mass.

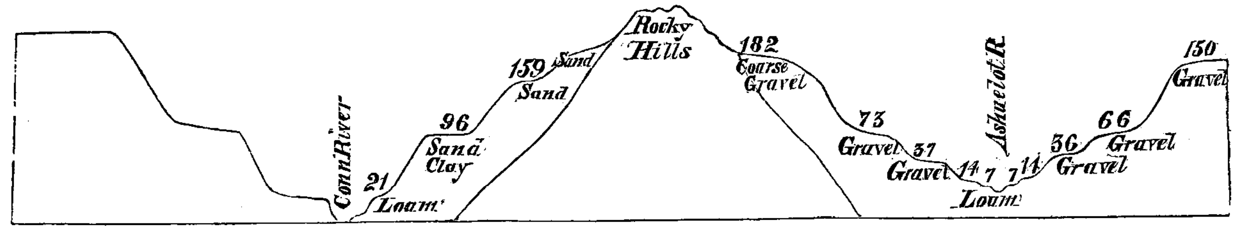
Fig. 48 represents a similar section upon the same river, running eastward in the north part of Northfield, only a short distance south of the State line.

To save prolix details, we have thrown together in a Table at the end of our remarks upon Old Sea Bottoms, the heights of all the terraces and beaches which have been measured in the State, both above the rivers, and above the ocean, where it has been possible. It is also designated by what process the height was obtained, whether by levelling, the Aneroid Barometer, or upon the authority of some person not connected with the survey. We have also marked the course of the sections upon the maps and upon the general map of the river (Plate III), except when an enlarged map of some portion of it has been given.

At the mouth of Ashuelot River, in Hinsdale, N. H., the terraces are numerous and instructive. The river is a small but rapid stream, and where it debouches from the hills into the Connecticut valley, it has brought forward a large mass of terrace materials, mainly of gravel, which originally constituted a delta terrace; that is, the stream threw forward these materials into the lake, or estuary, and formed a bank along its mouth. But as the waters drained off, so as to bring this bank above them, the Ashuelot cut through them, and formed lateral terraces along its margin. On the northern side of the stream, at its mouth, a rocky hill extends nearly or quite to the Connecticut, which is thereby forced at this spot to make a curve westward. The adjoining section (Fig. 49) passes across the Ashuelot near its mouth, directly through the village of Hinsdale, northwesterly over the hill, and then descends to the Connecticut, passing west of the river near the village of Vernon; so that all the terraces on the right of the rocky hills belong to the Ashuelot; while those to the left belong to the Connecticut. The difference in their height

and size on the two rivers affords a good illustration of the fact, that in general the larger the river the higher the terraces. The character of the materials, too, illustrates another fact, viz., that they are coarser on small and rapid streams, than on larger and more tranquil ones. Excepting the lowest, which are

Fig. 49.



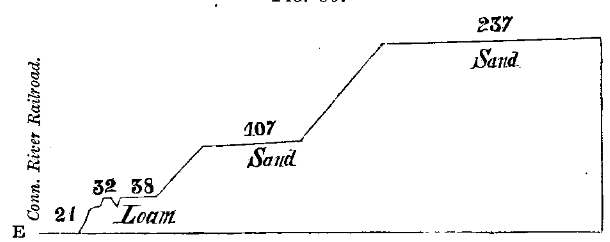
Section from Vernon to Hinsdale, N. H., across Connecticut and Ashuelot Rivers.

narrow, the terraces on the Ashuelot are all gravel, mixed with sand, and often the fragments are quite large; while on the Connecticut there are no pebbles of consequence, but sand underlaid by a thick bed of clay. A third circumstance deserves notice. On the Ashuelot the terraces have a rapid slope towards its mouth, corresponding to that of the river, which here falls so much as to afford a good site for manufactories; whereas on the Connecticut, the eye cannot perceive that the terraces are not strictly horizontal. Indeed, they probably decline but little from Brattleboro to this place, and the two higher ones are nearly continuous between the two places. The higher terrace along the Connecticut, not measured, is sandy and irregular, and deserves more properly the name of a beach.

By consulting Plate III, it will be seen that at South Vernon depot the rock approaches very near to the river. As we go north, the terraces widen, following a range of hills running westward, and then northward nearly at right angles to the first course, thus making the terraces to form a part of a basin within the principal basin. It is because this range of hills is composed of quartz rock (see Geological Map) that it is preserved, while the plain east of the quartz is underlaid by granitic gneiss, which decomposes more easily, owing to the feldspar in its composition.

Fig. 50 represents a section of the terraces on the west side of Connecticut river, in the north part of Vernon, and differs from the one described in Fig. 49, on the opposite side of the river. The height of the fourth terrace is greater; but the spot is not a great distance south of the gorge in the river at Brattleboro, and hence we should expect a greater amount of terrace materials. The terraces now begin to narrow on both sides, until they are entirely pinched out by the clay slate approaching the river banks upon both sides, yet they do not thin out at the same place; those on the west side are curtailed a mile or two before those on the east side.

Fig. 50.



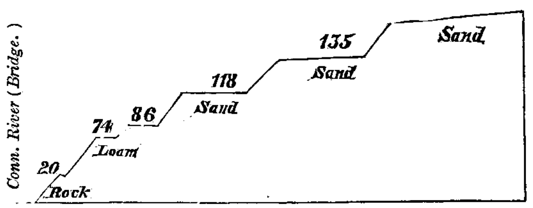
Section of Terraces on Conn. River on the west side, in N. Vernon.

TERRACES IN THE BASIN FROM BRATTLEBORO TO BELLOWS FALLS.

So narrow is the valley between Brattleboro and Westminster, that it deserves the name of a defile, rather than a basin. And yet terraces are found nearly the whole distance, though usually quite narrow.—Opposite Brattleboro, on the east side of Connecticut River, West River Mountain rises very precipitously to the height, above the river, of 1050 feet, and leaves no foothold for terraces. On the west side of the river, the hills rise more gradually. Within a distance of not over half a mile, two tributary streams empty into the Connecticut: the most northerly called West River, of considerable size; and the one at the south end of the village, small, and called Whetstone Brook. Such streams debouching in such a spot, and at right angles to the course of the Connecticut, are sure to produce numerous terraces. So numerous and complicated are they that a separate map of them has been constructed, which though not entirely complete is yet of great value in imparting instruction respecting river terraces. (See Plate VII, Fig. 2.)

The section represented as Fig. 51, commences at the west bank of the Connecticut River and the south bank of Whetstone Brook, and runs southwesterly to the top of the elevated sandy plain that passes into the basin, No. 5, just considered. (See the line of the section on Plate VII, Fig. 2.) The terraces appear to be the joint result of Whetstone Brook and of Connecticut River. They are, therefore, more numerous than is usual on the Connecticut, and less so than on this same Whetstone Brook, as the next section will show.

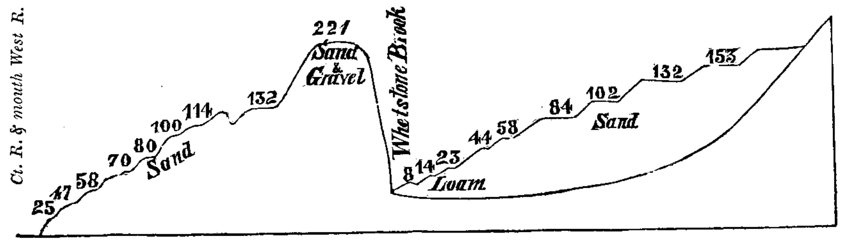
Fig. 51.



Section from Brattleboro Bridge (Ct. River) to the southwest.

The Connecticut Valley was probably occupied originally by terrace materials as high as the uppermost of the above terraces on this section, and when the waters gradually subsided, both the Connecticut and Whetstone Brook formed channels through those materials, and produced the successive terraces. Why terraces, rather than a continuous slope, were formed, will be shown in another place.

Fig. 52.



Sec. in Brattleboro from the mouth of West R. across the village and Whetstone Brook.

Fig. 52 shows quite an instructive section, commencing on the south bank of West River at its point of junction with the Connecticut, then extending southwesterly across the village of Brattleboro to the high bank of Whetstone Brook, a little west of the village, opposite Burge's factories; thence across the brook, and up the opposite bank, so as to cross the successive terraces, ten in number. The upper one was not measured, on account of the rain. Nor was the height of the brook, where the section crosses it, ascertained above Connecticut River.

It will be seen that No. 5, on the left hand part of this section, consists in part of an insulated hillock, crossed a little north of the village; and in the main part of a broad terrace, on which stands the upper and northwest portion of the village. This terrace, as was found by levelling, slopes towards Connecticut River, at the rate of twenty feet in fifty rods. Possibly this might have been in part the result of rains for a long period, bringing down from the hill deposits of sand, by which the terrace is bounded. More probably the terrace was formed by the conjoint action of West River and Whetstone Brook as a delta terrace, and that its slope was caused by the rapidity of the currents.

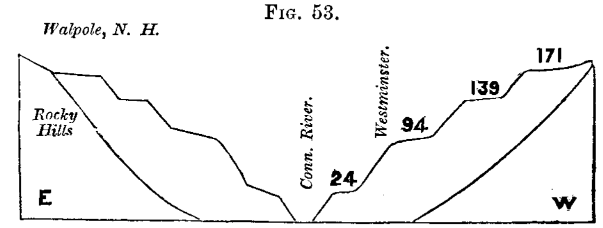
All these terraces are underlaid by clay slate, which shows itself all along the banks of the streams, and between the seventh and eighth terraces above the mouth of West River, on Fig. 52. It is doubtless this solid rock that has determined the present channels of the tributaries to the Connecticut, and caused them to enter that river at nearly right angles. The mere sand and loam of the terraces would soon be washed away, in time of freshets, were it not for this rocky formation.

We see here a good exemplification of the statement made on a preceding page, that smaller streams have smaller terraces than the larger streams, while they are much more numerous on the smaller streams. Here we have ten on Whetstone Brook, and nine on West River, yet they do not rise as high as the fourth on the Connecticut, in Vernon. It is just to add, however, that this larger number on the tributaries is shown best within a short distance, sometimes two or three miles from their junction with the larger stream, as in this case; for if we follow up Whetstone Brook the terraces grow less numerous. Passing west of the highest terrace of the Connecticut, at an axe factory, three-fourths of a mile west of the village, we find five terraces on the south side, instead of the ten at Burge's, and Nos. 1 and 5 upon the north side.

Near West Brattleboro, two miles west of the principal village, there are four terraces on the south side, and none upon the north. Although these terraces are lateral, we find them at successively higher levels, so that there are at least a dozen different levels by the time we reach the west part of the town, where two streams unite. Here is quite a large oval meadow, surrounded by terraces (five upon the east side), particularly by quite a large one, No. 4, whose distinctness is very conspicuous. It seems as if it must have been formed by a barrier. If so, the blockade must have been somewhere in the Connecticut, and that at a height of 400 feet above its present level; for this terrace, which is not the highest, is 401 feet above the Connecticut, as indicated by the Aneroid. For five miles farther west, we still find terraces in ascending this brook—and quite high ones—which unfortunately are not accurately mapped or measured. At 1133 feet above the Connecticut are found loam, sand and water-worn pebbles, which have somewhat the appearance of an old sea beach. We should expect to find a beach here, as they very frequently occur above remarkable developments of terraces.

Passing north from Brattleboro into Dummerston we find little but clay slate, cropping out at intervals, until we reach a brook coming down from Dummerston Center. Here, as we often see, the highest terrace (No. 5) curves and passes up the stream for half a mile, and then curves back upon the north side of the branch until it is on a line with its course south of the stream, when it proceeds on its northerly course parallel with the river. The meadow and other terraces, as at this place, curve with the highest terrace.—The next point of interest is in the south part of Putney, where five terraces are formed by a small stream from the northwest, on each of its sides, as it crosses the terrraces belonging to Connecticut River. They pass up the small stream for some distance. Fig. 53 exhibits a section, commencing with the highest distinct terrace in Westminster, a little south of the village (which is located upon the second terrace reckoning upwards), and crosses the Connecticut into Walpole. Only the heights upon the west side are given exactly — those in Walpole having been marked as they appeared from the west side. They are very distinct on both sides, and perhaps they correspond in height, though usually, in such cases, actual measurement shows considerable difference in elevation, where the eye can detect none.

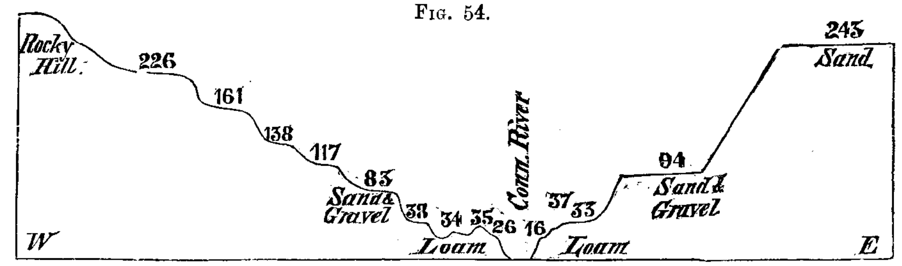
Fig. 53.



Section across Ct. River from N.W. to S.E. at village of Westminster.

At the upper end of the basin under consideration, the terraces are numerous and distinct, just below, as well as above Bellows Falls in the next basin. The section represented in Fig. 54 crosses Connecticut River near the mouth of Saxton's River on the west side, and near the mouth of Cold River on the east side. Of course the terraces are compounded of the effects of the three rivers. It will be seen that there is no correspondence in their height on opposite sides of Connecticut River, except that the upper terrace very probably once filled the valley; for the difference in height between the opposite terraces (17 feet) is not greater than we might expect on the supposition that the materials were drifted into a former lake, or estuary, by the adjacent streams. These materials are, for the most part, coarse sand, sometimes mixed with gravel. On the east side ledges of rocks appear on the slope of a third terrace.

Fig. 54.



Section across Conn. River in Westminster and Walpole, N. H., near the mouth of Saxton's and Cold Rivers.

As an illustration of the manner in which terraces occur, a sketch of the terraces of the above section, as they appear about a mile south of where it crosses Connecticut River, on the road to Walpole, is given on Plate IV, Fig. 1. It was originally sketched by Mrs. Edward Hitchcock, and then lithographed for the *Illustrations of Surface Geology*, from whence it was taken for this plate. The view from this spot of the gorge with its terraces, and of some of the principal buildings in Bellows Falls, is excellent. It is a good sample of the very artificial appearance of many localities along the rivers of Vermont. Were they not so extensive, one would be tempted to ascribe them to the agency of man. The sketch was taken from the second terrace on the east side of the river.

The two irregularities marked A, on the first terrace on the west side of this section, are the two glacis terraces which have already been noticed in an enlarged section in Fig. 46, and the section may be found on the enlarged map of Bellows Falls, in Plate IV, Fig. 2.

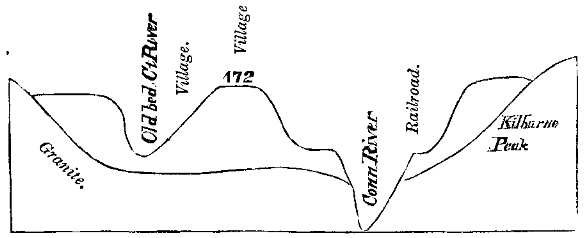
TERRACES IN THE SEVENTH BASIN.

The mountains at Bellows Falls crowd closer upon the river than at any other place south of this spot; except perhaps Mt. Holyoke and Mt. Tom, in Massachusetts. On the west side, as at Brattleboro, the mountains recede farther, and have an escarpment less steep; yet the rocks show themselves almost everywhere in the gorge, and form a ridge which produces the falls. All the circumstances here are favorable to the formation of terraces. The section on Figs. 46 and 54 is only a mile and a half south of the village of Bellows Falls, and the highest terraces extend through the village into the seventh basin.

A separate map is given of the terraces at Bellows Falls, which may be found on Plate IV, Fig. 2. It presents a case of rivers uniting in a larger stream upon opposite sides. The Brattleboro case is where two streams enter the channel quite near each other, both upon the sàme side of the larger river. Many other modifications may occur when the tributary and principal stream have different relations to each other.

Fig. 55 represents a section crossing Connecticut River directly through the village of Bellows Falls, and a few rods above the principal cataract. The heights are given from the foot of the falls. The depression on the left was evidently once occupied by the river, when at a higher level.

Fig. 55.



Section across Conn. River at Bellows Falls, (above the old barrier.)

As we go north, the terraces increase in number on both sides of the river, until at the mouth of Williams River there are five and a beach upon the west, and four upon the east side of the Connecticut. The beach, which is much worn, is at the village of Rockingham, on the tongue of land between Connecticut and Williams' River; and beyond this point it is mostly worn away, and its place is supplied by a sloping hill of gravel and sand.

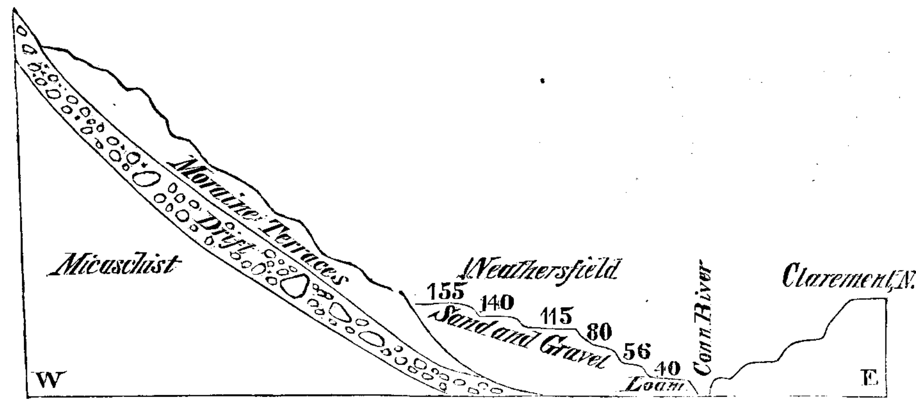
Upon the east side of the Connecticut, in Charlestown, N. H., the terraces increase in width until opposite the mouth of Black River, from which point they diminish in interest and frequency. At North Charlestown, and from the mouth of Black River northwards on the Vermont side, there are no terraces.—The river flows through a narrow valley, whose sides slope evenly to the water's edge, most of the way from Black River to Weathersfield Bow. Perhaps the rounded contour of the mica schist hills may be covered with soil; but we were unable to examine the surface, except from the east side of the river at considerable distance.

This dearth of terraces is due to the fact that the river formerly ran through Claremont and a part of Charlestown, in another channel, during the period when the terraces were principally formed. Hence we find terraces skirting the valley of the former bed, while since the river has occupied its present channel its agency has been employed in wearing out a passage for itself through the solid rocks.

TERRACES IN THE EIGHTH AND NINTH BASINS.

The eighth basin, from Springfield to Mt. Ascutney, is about ten miles long. It commences lower down on the east than on the west side of the river, because of the accumulations about Claremont, upon the old bed. These are quite high and extensive, constituting the fifth terrace, and are mostly composed of sand. Upon the banks of Sugar River the terraces are small and numerous, the river crossing the high terraces of the Connecticut. To the north, the larger terraces are gradually lost on the approach to the northern limit of the basin in Cornish, N. H. Upon the west side of the Connecticut the terraces commence near Weathersfield, on the great bend. The village of Weathersfield is situated upon the second terrace. The terraces are finely developed as we go north, and Fig. 56 represents a section crossing them

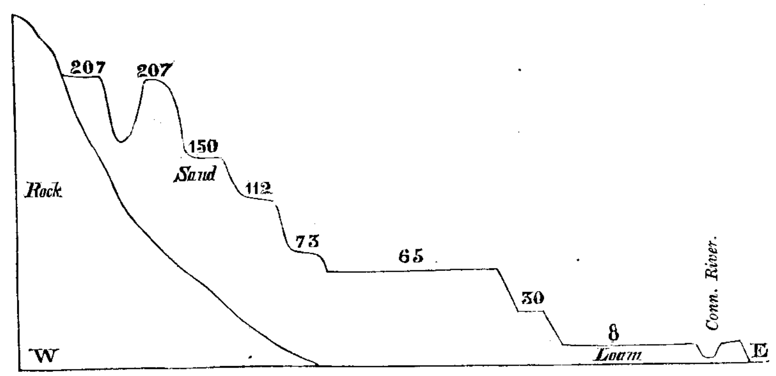
Fig. 56.



Section of Terraces on Conn. River near the north lines of Weathersfield, Vt. and Claremont, N. H.

near the north town lines of Weathersfield and Claremont. As usual we find loam upon the lowest levels, and sand with some pebbles upon the higher terraces. The tops of the terraces are quite even till the sixth is reached, which is undulating. The section extends four miles west of the river, and shows moraine terraces more than half the distance, extending nearly to the top of the ridge separating the valleys of the Connecticut and the tributaries of Black river. Underneath the moraine terraces we have represented the unmodified drift, which was found upon the top of the ridge, and is supposed to underlie the modified and water-worn materials. Upon the east side four terraces were observed whose heights were not obtained. The measurements were taken with the Aneroid Barometer. The fifth terrace on the west side, though quite narrow, extends into the ninth basin to the village of Windsor, where it is cut in two by a mill stream, entering the village from the southwest on the stage road to Felchville and Cavendish. The union of the two currents has produced six terraces lower than No. 5 of Connecticut river, upon the north end of the latter. Another small stream empties into the Connecticut just north of Windsor; hence No. 5 has a large part of its materials carried off, its western border alone being left, which passes around the village west, where its limit is reached at the bottom of a still higher terrace, No. 6. The two streams have left a tongue of terraces between them, mostly No. 4, upon which the village of Windsor is built. The

Fig. 57.



Section of Terraces on Conn. River, in Windsor.

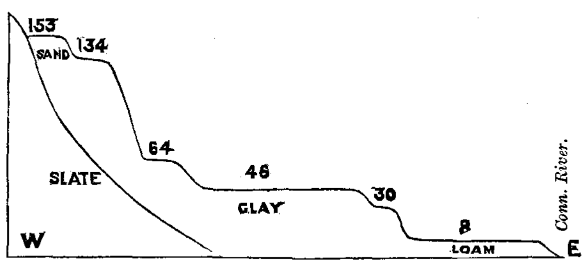
plain upon which the State Prison is located is No. 4; while the Cemetery occupies both Nos. 3 and 4, and the principal street running north and south is upon No. 3. The railroad passes on No. 1, the meadow. A map of all these terraces is given on Plate IV, Fig. 3.

North of Windsor, on the road to Hartland, the above section, Fig. 57, shows the occurrence of seven terraces. They were probably formed by a former bed of Connecticut river, passing around an isolated elliptical-shaped No. 2 terrace, which will be seen on the map just referred to, a little north of Windsor village. In this case the Connecticut has worn away materials from one of its own terraces, and has arranged them in this form. Though the highest terrace here is the seventh on the section, it is placed on the map as connected with No. 6, above and below this point, and it is of the same height with them. Hence we consider it as the sixth terrace, as a whole, and the seventh in this particular place. This high terrace, as the section shows, has been partially worn away. There is no stream in this valley, but it seems to have been eroded by rains, which have marred the outlines of the higher terraces so much all along the river. This valley is not an old bed of the river, for it is not continuous to the river. This section was measured with the Aneroid, which did not work very satisfactorily. It does not give small heights very correctly.

The higher terraces occupy most of the surface of the valley to North Hartland, except where small tributary streams have worn a passage through them, as at the village of Hartland, or meadows have been formed by the former bed of the Connecticut. The material of the highest terrace is sand, and the lower terraces are formed of clay.

At North Hartland the Otta Quechee River unites with the Connecticut, and the map shows that a large part of the higher terraces has evidently been worn away, leaving a pretty basin of the smaller terraces in their place. The adjoining figure (Fig. 58) represents a section of the terraces formed by the confluence of the two rivers. The section runs just north of North Hartland depot, and south of the Otta Quechee. The depot is upon the same level as No. 3, in the section. The meadow is quite extensive here.— This section was measured with the Aneroid. It is interesting to notice that No. 6 of this section is of nearly the same height as No. 6 of the previous figure, (57), differing only three feet; and that No. 4 of this section, and No. 3 of the previous, differ in height only one foot. This may not be the result of accident. Upon the New Hampshire side of the river, the terraces are few, or of small size in the ninth basin, until we reach the town of Lebanon, above the mouth of the Otta Quechee, where the meadow is very wide, and four large terraces occur beyond it. The valley is quite wide here, but narrows quite rapidly to White River Junction, and then more gradually to the limit of the basin, at the line between Hartford and Norwich, where mica and hornblende schists form the banks.

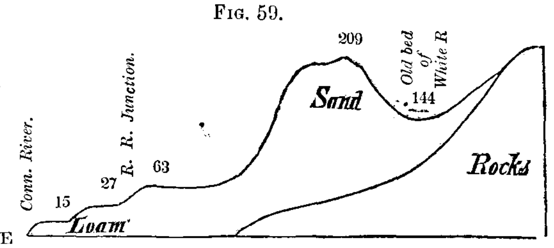
Fig. 58.



Section of Terraces at the confluence of Otta Quechee and Conn. Rivers.

The section in Fig. 59 was measured by us in 1854, with the Aneroid barometer belonging to Dr. Hitchcock, whose range has been more accurately determined than that of the instrument belonging to the surveying party. The section commences at Connecticut River and passes west through the Railroad station. The old river bed on its west part was formerly probably occupied by White River, which then entered Connecticut River a little below the present junction. The composition of the highest terrace is well shown, for the bank is so steep that nothing can grow there, and the explorer finds to his sorrow, especially if he wears shoes, that sand is plenty even at 200 feet above the present level of the river.

Fig. 59.



Section westward from Ct. River, at White River Junction.

BASINS FROM NORWICH TO WATERFORD.

The valley grows narrower after leaving White River Junction, the Connecticut grows smaller, and has a swifter current,— still at times the valley widens, and the terraces are quite numerous.

The tenth basin is confined to the town of Norwich, and at the first the rocks press closely upon it. The materials are fine, but are deposited at the proper places, even though the rock permits but little surface for it to rest upon. It seems to be a law in the deposition of terraces: that at regular intervals an attempt should be made to form a bank, and that when a shelving surface excluded much material, all was deposited that could possibly be retained, while the remainder was carried farther down the stream, to find a more favorable spot for its resting place.

Dartmouth College is situated upon one of the higher terraces on the east side of the river. This terrace extends some distance north and south, and almost touches the bank of the river, allowing however two smaller terraces to intervene. In a valley east of the observatory was probably an old bed of the Connecticut. We traced this bed a couple of miles north, but did not examine its southern prolongation to learn its reunion with the present bed of the river. Upon the Norwich side the terraces cling to the bank of the river, and are separated from the village by ledges of rock. The strata of clay in the third terrace dip ten or twelve degrees to the west, and contain concretions. The village is situated on a plain; and it is worthy of inquiry to ascertain whether this level tract may not be in some way connected with the Connecticut, either as an old bed or the tongue of a high terrace. We were unable to determine this point.

The terraces continue in great force to Pompanoosuc village in North Norwich, especially on the Vermont side; and the highest terrace, the fourth, passes over into Thetford, the eleventh basin—a ledge of rock showing itself for some distance on the east side at the boundaries of the two basins.

At South Thetford station there are three small terraces on each side, and the meadow is well developed in the village. To the north their places are occupied by No. 4, which in turn, at North Thetford, divaricate at a considerable angle; so that the valley is wider than at any place between this and South Lebanon. Four terraces occur on both sides, succeeded on the east by an old shore or beach. Upon the third terrace, east of Thetford village, and 140 feet above Connecticut river, there is a pond covering ten acres of surface, having neither outlet nor inlet. A gorge shuts out this beautiful basin, as we travel swiftly northward, and after riding a moment in a narrow rocky defile,—for we will suppose ourselves seated, in our rapid survey up the river, upon a railroad car expressly fitted up for Geologists: so arranged that we can have ample opportunity to see the country both sides of the track—after the moment spent in the gorge, the curtain, as it were, suddenly rises, and shows us the twelfth basin, in Fairlee. Though it is the shortest, it is not the least attractive: the wide meadow and the trim terraces, none of them very high, remind us rather of the pleasure grounds of some nobleman, and we almost expected to find his cattle at every turn in the road, or see the timid deer of the hunting grounds on the hills, scampering from our gaze. But we see instead, beautiful farms, and such indications of thrift as show the prosperity of all classes—a much pleasanter sight in a free country than individual lordly magnificence. At the southern extremity of this basin we find an old river bed passing around a higher terrace, leaving it like an island. It is No. 3 surrounded by No. 1, and the latter joins the river only just above the gorge.

Passing into the thirteenth basin, which commences at North Fairlee, and continues to South Newbury, eight and a half miles, we find a wide meadow, with terraces on either side, varying at different places from two to four, until we reach the village of Bradford, at the mouth of Wait's River. This stream, by uniting its forces with the Connecticut, has produced high and extensive accumulations of fine materials. Four terraces curve from their straight course on the Connecticut, and pass up this tributary for some distance, on both sides. The village of Bradford is upon the lower terraces, while some buildings are placed upon the highest bank; one of which, a peculiarly shaped polygonal tower, used, we understand, for a town clock, attracted the attention of the Geologists, almost as much as the terraces; and the theories of the party, respecting its use, differed as much as the theories of scientific men respecting the origin of terraces.

Nearly opposite Wait's River, No. 4 is of large extent on the New Hampshire side, reaching to the river. This gives place soon to Nos. 1 and 3, which extend to the end of the basin. The highest terrace on the

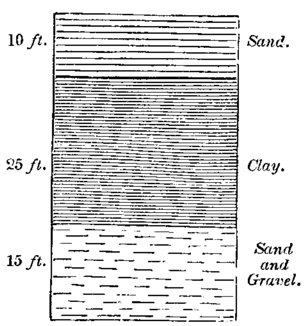
Vermont side, No. 4, extends north beyond the limits of the thirteenth basin, and becomes the fifth terrace at Newbury. This is caused by an old river bed, which at a curve above Newbury village has made a number of small terraces, insomuch that two unusual terraces are *interpolated* between the second and fourth. This will be seen to advantage upon a separate map of the surface geology of Newbury (see Plate V, Fig. 2), at which place we were enabled to make more accurate observations than at any other place between Hartford and Waterford.

It is in the fourteenth basin, which at the village of Newbury is very wide, perhaps wider than at any point below in Vermont, that these terraces are developed. A view of Newbury and vicinity from Mt. Pulaski exhibits much of the geology of the country. While it shows the terraces but imperfectly, considering their remarkable extent and regularity, it will give a good idea of the configuration of a basin of terraces, showing as it does, the great depression prepared by nature, and its successive adornment at lower levels by meadows and terraces; at a higher level by a sea beach, and still higher by the drift and naked rocks, whose projecting summits present a surface to be acted upon by storms and currents, thus eroding materials for alluvial deposits.

In examining the terraces at Newbury, we notice, first, an old river bed, continuing in a straight course from the river above the bend, two miles north of the village. It continues south till near the village, when, upon the second terrace, it makes a turn to the east, following the course of the Connecticut and Passumpsic Rivers Railroad to the depot, when it proceeds to the Connecticut along the valley of a small stream. It is at the bend of the old bed that the interpolated terraces are found, being formed at intervals formerly, just as in similar situations they are now produced. North of the village there is a ridge extending a mile and a half to the Connecticut, in a due north and south direction. This at first is rock, and is doubtless underlaid by rock the whole distance. Next we find No. 6, then No. 5. West of this ridge is a valley, through which the old river bed, already mentioned, passed, where are several terraces and another interesting former bed. The village is mostly upon the sixth terrace: a seventh being imperfectly developed to the south.

Fig. 60 represents a vertical section of the terrace upon which Newbury is built, No. 6. The relations of the sand and clay can be seen clearly at the spot where the railroad has cut through the terrace, and an arched bridge prevents the top from falling down. The first ten feet in the descent are composed of sand, which is the only material on the surface in the whole village. Next comes clay, 25 feet thick by estimate, a blue, silicious, more or less indurated clay, such as is common along the whole valley of the Connecticut. Below this, on the section, we have placed 15 feet of sand and gravel, but it reached to an unknown depth, this thickness being used for convenience, that the section might show the composition of the terrace as low as the level of the river. A careless observer might think that the loam on the north side of the railroad (between the depot and the river), in the meadow, ought to have taken the place of the sand and gravel, as it is lower down. But according to our view, as shown on Fig. 39, facts show that the loam is higher up geologically, and therefore, though it may occupy a lower topographical level it does not run under the clay, as may be ascertained by inspection. This section may also illustrate the relative position of clay and sand, not only in the Connecticut Valley and in Vermont, but all over New England, and perhaps the United States. Clay is found universally lying under sand, and there must have been some general cause for this order, though the overlying sand is often removed, or may not always have been deposited: just as Potsdam sandstone is sometimes wanting between calciferous sand rock and hypozoic rocks.

Fig. 60.

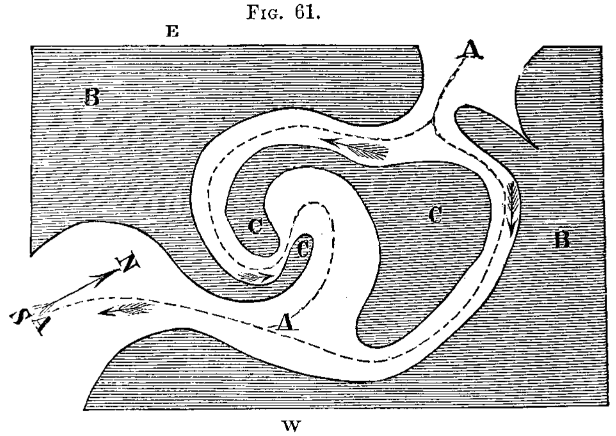


Vertical Section of the 6th Terrace at Newbury.

The meadow is very large, the windings of the river being through this terrace exclusively. Doubtless former courses through this flat can be easily traced. Upon the east side of the river the terraces are more continuous than in Newbury. The second terrace occurs at intervals and is very small; the third and fourth are wanting, and the fifth and sixth are very wide and extend north to Wells River, bending with the river about two miles north of Newbury. Fig. 61 represents some curious shapes which the highest

terrace has assumed by the wearing of a small stream. Our attention was called to it in 1857 by the Rev. C. W. Cushing, A. M., President of Newbury Seminary, who kindly showed us also other points of interest in the neighborhood, and subsequently sent to us specimens of rock from his vicinity. The elevations are indicated by lines, the valleys constitute the remaining part of the figure. Originally, the whole was of the same level as B B, or terrace No. 6; but the valley through which the sluggish streams A A pass, in a morass, is fifteen to twenty feet below the surface of the terrace. A few feet of C C have been removed. From the elevated land B upon the left of the figure, a sort of a hook runs around a similar hook, extending from C C. The strip from B upon the left, is nearly worn away, a bank of only about three feet depth and four feet width remaining to connect with the extreme point C. This narrow neck must have been worn by the current on the left hand, as it is directly in its natural route, as the arrow indicates. The agency by which the sand has been thus singularly removed must be water, and that from occasional freshets, as this spot is near the head waters of the stream. But the sand is so light that a very gentle current would easily remove it. Had the current been stronger, doubtless the excavation would have been more nearly straight. Passing to the north, when above the terraces, we come to an old beach, whose counterpart upon the opposite shore of this former narrow estuary, may be found upon the hills west of Newbury, at a height of 1488 feet above the ocean.

Fig. 61.



Erosions in a Terrace in Haverhill.

Jumping upon our Geological Train again at Newbury, we pass by ledges of slate, fractured by the drift agency, and arrive at Wells River. Here Wells River enters the Connecticut on the west side, and the Lower Amonoosuc on the east. Hence these three rivers have accumulated much material, which is arranged in terraces on each, there being four terraces upon each side of the three rivers. Those on the Connecticut diminish in size and finally become obsolete at the south line of Ryegate, where a gorge succeeds.

The fifteenth basin extends through Ryegate to McIndoe's Falls in Barnet, a distance of eight miles.—The terraces are of less size than those in the fourteenth basin, and generally the fourth terrace is wanting entirely on the east side, except a limited fragment at Canoe Falls, where there is also a kind of a beach. The fourth terrace extends the whole of the distance on the west side, and is generally accompanied by others.

At McIndoe's Falls commences the sixteenth basin, where rock forms the western bank, and the third terrace the eastern. The terraces are generally small and scanty, amounting, however, to five in number, where the Passumpsic River empties into the Connecticut. We seem, however, to have entered upon a district where the bed of the river is mostly rocky, relieved occasionally by a few feet of soil. There are several falls on this basin, and indeed before its northern limit is reached, commences the "Twenty Miles Rapids." Although to a geologist's eye the terraces are very few in number in this basin, it is evident that the farmers of this region think otherwise. Hence their enterprise has given birth to an invention, which is not *patented*, we believe. Mr. Enos Stevens of Barnet, a son of Henry Stevens, Esq., not willing to wait for the slow operations of nature to work out their results, has applied reason to assist inanimate matter. Upon his land there was a high bank and a piece of low wet land, neither of which *were* of any great value. Near by is a small stream which had been doing what it could, in its senseless way, to wear down the bank. But like other brooks, this one was of little use to accomplish this work, because it was so small. Mr. Stevens saw that he might assist in this work. Therefore he changed the course of the stream in the time of a freshet, making it pass through that portion of the bank most easily removed. Obedient, the stream carried down the gravel and sand into the low land, and, by regulating the course of the stream for a time, the water removed the major part of the bank, and carried it into the morass. Hence the hitherto unprofitable hill has now become levelled down to a handsome meadow, ready to yield its fruit in its season.—This is an example worthy of imitation, which will no doubt be followed when the intelligent people of the State shall have had the plan suggested to them. Indeed, so happy a thought has entered more than one mind already. When in Rochester in 1858, we heard of a person there who had been doing the same thing upon his farm. Perhaps it would hardly be advisable to enlarge upon this topic, lest the inhabitants of the terraced villages throughout the State should take it into their heads to remove *all the terraces* in this way. That process would not be desired by geologists, or others, who would then miss one source of the beauty of the landscape. The future geologist in such a country, where the terraces had all been worn down in this way, might find a great many old shores, or beaches. For he would find water-worn materials of great thickness, sloping towards the rivers, and he would reason that they must have been made by waves quietly washing the shores of a lake, or something of that sort.

But we must return to the sixteenth basin. After passing the mouth of the Passumpsic, a few small terraces are seen as far as Waterford. Here at the limit of the basin, there are three terraces on both sides of the river, wider and finer than any others above Stevens Village; which give place to two old beaches or shores. Near this point we find that the Connecticut changes its north and south course, first running west, and then southwest, as we advance up the stream. The straight course we have been pursuing, in our scientific journey, would carry us into the valley of the Passumpsic. The twenty miles falls or rapids commence a short distance before we reach the limit of the sixteenth basin, and within this area the seventeenth basin is located. About ten miles of this territory has not been examined;—but from indications observed at both ends of the terra incognita, it was presumed to be a country very deficient in terraces. Occasionally a few appear, as at the bridge between Waterford and Littleton, New Hampshire—and over a part of the distance there may be an imperfect kind of a beach. We would hazard a conjecture concerning the cause of this deficiency of terraces and terrace materials along this interval, while below, at Wells River, and above, at Lunenburg (upper part) and Guildhall, they are so abundant. We would conjecture that the Connecticut formerly left its present bed a little below Lancaster, N. H., then passed to Whitefield over the summit level, across two ponds of water, into the valley of the Lower Amonoosuc River to Littleton, and followed that stream down to the mouth of Wells River, where it entered its present bed. We would present the reasons for this belief:

1st. It would be a *more direct route* for the Connecticut than the present. To be sure, rivers do not seem to be very particular as to the route they take in threading their way among the hills; but, as for all the rest of its course in Connecticut, Massachusetts and Vermont, it is comparatively straight, there is some reason to think that a straight course for the rest of the way would have been the most natural. This straight course has generally been determined by the eastern limit of one of the rock formations, an easily decomposing rock. Now on its present route the rock is different in its character, being tough breccia or talcose schist instead of calciferous mica schist. On the Amonoosuc route the rock is mainly granite, which is easier to decompose than the talcose schist. This route would have saved six miles, at least.

2d. *The character of the terraces* along the two routes, and above and below the ends of the supposed bed. Below Wells River, the terraces are remarkably fine—so they are above Lunenburg—while between Lunenburg and Wells River on the Connecticut, they are very poor below the mouth of the Passumpsic, and above that point are generally entirely wanting. Upon the Amonoosuc River they are well developed. Hence it seems more natural to suppose that a continuous set of fine terraces was formed by the same stream, when that stream had the power to produce such brilliant effects as the Connecticut does, than to suppose the contrary. The fact that from Wells River to Stevens Village (Barnet) there are some terraces, and none of any consequence above it, except on the Passumpsic River, would seem to indicate that the Passumpsic was the main producer of the terraces above Wells River, and that the Connecticut changed its course so recently as to have had little effect upon the formation of terraces there.

3d. This supposed bed is on the route of the proposed railroad from Littleton, N. H., to Lancaster, N. H. Its summit level is 650 * feet above Connecticut River, and if this measurement was taken from the mouth of Wells River, as we should suppose, it will be only 230 feet above the same river at Lunenburg, and 197 feet above Lancaster, N. H. This would not make this bed so high above the present level of the river as others which we consider as well established cases. All that remains to settle the point is to visit the ground, and see whether there are any special evidences of water action along the highest part of the route. Had we suspected such a thing when in that district, we should certainly have examined it. If this ancient bed was once occupied by the Connecticut, then may we say that geology throws light upon ancient boundaries of States. For the Connecticut is the established boundary between Vermont and New Hampshire. When therefore the river occupied this old channel, Vermont encroached on New Hampshire, and owned some forty or fifty square miles more of territory than at present. When we come to speak of old river beds we think we can give an adequate reason for this change of location.

As already stated, we have little to say of the seventeenth basin, or between Waterford and the Cat Bow in Lunenburg, except that the whole course is probably rocky. The next basin presents a marked contrast to this.

BASINS FROM LUNENBURG TO CONNECTICUT LAKE.

There are at least five basins in this region, one of the most fertile for agricultural purposes in the State. The first of them, or the eighteenth from the mouth of the Connecticut, extends to the north line of Guildhall, a distance of seven miles. In South Guildhall, opposite Lancaster, N. H., the meadow is remarkably wide—so wide indeed is it that we could not see from the west side how many terraces there were on the east side. This has not been so before since leaving Massachusetts. The terraces are developed in beautiful proportions in Guildhall, especially about two miles west of the court-house, where there are seven terraces, the product of the joint action of the Connecticut and a small stream coming down from Granby. These are in a kind of sub-basin, a valley running west among the mountains, so that the Connecticut must formerly have made quite a bend. The second terrace is the most extensive of them all, forming a plain more than a mile wide. It is the meadow in Guildhall. In Northumberland, on the New Hampshire side, a high ledge of granite comes close to the river, cutting off all deposits. And soon the granite from the Vermont side approaches the river, and we see the barrier or limit of the basin.

We were reminded very much of Bellows Falls in Guildhall. For in both places, the general features of the geology as well as the topography are the same. The high hill of granite in Northumberland is shaped like Kilburne Peak, opposite Bellows Falls; and in lithological character the mountains agree, as well as the adjacent rocks across the river.

Passing into the nineteenth basin, in Maidstone, we find quite a wide valley, with well defined terraces, and quite large accumulations of sand and loam. The number of terraces varies, especially upon the west side, where the highest terraces are sometimes wanting. On the east side the fourth terrace is constant. In this basin, opposite Maidstone and Brunswick, is the route of the Atlantic and St. Lawrence Railroad, which crosses the Connecticut into Vermont at the south part of Bloomfield, passing up the Nulhegan River to Island Pond. The latter river acted with the Connecticut in forming terraces, and the map shows at this point a combination of lateral and delta terraces. Soon this basin narrows, and its limit is in North Bloomfield, eighteen miles above the south line of Maidstone.

We are now in a very romantic country. The traveler sees a constant succession of very high mountains, whose tops, sometimes of great extent, or mere conical points, are either clothed with verdure or are simply white granite, glistening in the sun. If it be not fair weather their tops are obscured by clouds, or their summits appear above the clouds like islands in the ocean; and in fact they then show us what was their appearance before the formation of the terraces, when the waters of the ocean extended to where the

* We are under great obligations to Mr. John T. Coffin, of Laconia, N. H., for sending us copies of a "Plan of a Survey for the White Mountains Railroad." This map has been of great service to us in sustaining this conjecture of the former course of the Connecticut. It is our authority for the heights specified.

clouds are now. As the wind has moved these clouds, we have at times almost fancied that these clouds were the waves of the sea washing the summits, and that we saw the face of the country as it appeared in former times.

At the south end of the twentieth basin the highest terraces, No. 4, are the only ones in view, but they expand so as to receive the lower ones within them before arriving at Colebrook, N. H. Here an old bed of the river has interposed No. 3 between Nos. 1 and 2, and has produced other variations, which are represented upon Plate III. Mt. Monadnock in the northeast part of Lemmington, extends to the river, and forms part of the northern limit of this basin. The length of the basin is five and a half miles. Passing still farther to the north, in the towns of Canaan and Stewartstown, N. H., we find still a fine country, with well developed terraces, though the valley is not very wide. In the twenty-first basin of six miles extent, we find great variety in the number, extent and position, of the terraces. Just below the village of Canaan, a rocky barrier limits this basin. At Canaan commences the twenty-second basin, and it is finely developed. A stream comes in from Canada, from Leach's Pond in Averill, uniting with the Connecticut at the village of Canaan, and assisting in the formation of six beautiful terraces on the west bank of the Connecticut. The highest of these is also found on the New Hampshire side. This is the last interesting portion of the river for terraces, that we saw, though we went but a few miles farther. The Connecticut has now dwarfed to a width of 150 feet, from 390 feet at Newbury and from 450 to 1050 feet in Massachusetts and Connecticut, and its forces are divided into various tributary streams. We have represented the space of sixteen miles intervening between Canaan and the head waters in Connecticut Lake, in New Hampshire, as forming only one basin, because we have not examined the last twelve miles of its course, and therefore do not know the character of the valley. But we presume, from appearances indicated at the limit of our explorations, that the terraces are quite limited in size and number, in this district. We should have been glad to have examined the shores of Connecticut Lake for any terraces or beaches about its waters. We know by report that the country is very wild, and perhaps the extent of the unbroken forests would prevent the easy acquisition of the desired information.

We have now stated what facts we have learned respecting the terraces in the valley of the Connecticut River, in Vermont and New Hampshire. Before leaving this valley it becomes us to say what we can respecting the terraces upon its principal tributaries in Vermont: West River, Saxton's River, Williams' River, Otta Quechee River, White River, Wait's River, Wells River and Passumpsic River. Our task will be easy, because of the scarcity of observations.

TERRACES UPON BROAD BROOK AND WEST RIVER.

Broad Brook runs through the north part of the township of Guilford, and empties into the Connecticut in the north part of Vernon. At Algiers, the highest terrace on the south side, or No. 3, attracts attention by its size and great height. It constitutes quite a marked plain, and is 497 feet above the ocean. A small stream flowing from the south by the slate quarries, unites with Broad Brook at the foot of this terrace, and appears to have been largely concerned in the formation of these terraces. Other terraces less marked may be seen upon Broad Brook, both above and below Algiers.

West River rises in Winhall, Londonderry, and Weston, emptying into Connecticut River at Brattleboro. It has had an important part in determining the number and outline of the terraces on the Connecticut, north of the village of Brattleboro. The few glimpses we have had of its surface geology above Brattleboro, have satisfied us that terraces are developed upon its banks in unusual profusion. We were particularly impressed by a view of the valley of West River from the vicinity of the old court house of Windham county. The whole valley for a great distance could be distinctly seen wending its way among the mountains, like some of the fancied views in fairyland.

Although we traveled three or four miles along the valley of West River, we have scarcely any specific statements to make respecting its terraces. Between Black Mountain in Dummerston and Fayetteville, they were certainly very numerous and well developed. No. 4 is represented upon the map on both sides of the river in this section. Four terraces at the junction of West River with the branch from Williamsville

deserve special mention. The only others represented upon the map, are a few of no special interest upon the branch of West river in the east part of Townshend, and a very pretty one in the village of West Wardsboro, upon another tributary.

TERRACES UPON SAXTON'S AND WILLIAMS' RIVERS.

Saxton's River unites with the Connecticut below Bellows Falls, and assisted in the formation of the complicated terraces about the gorge there, already described. Upon Saxton's River there is a very decided rocky barrier of granite, only a quarter of a mile from its mouth, above which there is a very pretty basin of terraces near Bellows Falls village. On the north is the highest terrace of the two rivers, a similar one is on the south side, on the east is the rocky barrier, while between is a meadow, the whole forming a beautiful amphitheatre. This basin extends near to Saxton's River village. We regard the terraces about this village as forming a second basin, and the location for the village was well selected. Another basin includes the village of Cambridgeport. Between Saxton's River village and Cambridgeport there is an old beach, or shore, upon the north side of the river. The current of Saxton's River is more rapid above Cambridgeport, and consequently it is difficult to mark the different basins with precision. There are also traces of a former glacier in the valley, on which account the terraces may not be so numerous. The Cambridgeport basin terminates about a mile above the village. At this point numerous large bowlders form a conspicuous feature of the landscape. The river makes a great bend just below Eagle Mills. South of the angle of this bend, Nos. 4 and 5 may be seen upon the west side, and No. 4 upon the east side. These terraces are large and conspicuous. At Eagle Mills there is no terrace upon the south side, but Nos. 1 and 3 occur on the north side. Between Eagle Mills and Houghtonville, terraces occur upon both sides of the river without interruption, but none of them are continuous. There are never more than four at any one locality. Their general distribution is shown upon Plate II. At Houghtonville, Nos. 1 and 2 may be seen upon the south side, and Nos. 1 and 3 upon the north side.

On *Williams River* there are at least three basins. The first extends from Connecticut River to Bartonsville. The terraces are remarkably numerous in this basin, there being ten on both sides at intervals. As will be seen from the enlarged map on Plate VII., Fig. 1, No. 5 of Connecticut River on the south side, and No. 4 on the north side, unite with the highest terraces of Williams' River, and form lateral terraces to the first great bend in the river at Bartonsville. They are the terraces out of which the others have been formed. They seem to have the same height above the river, and were probably formed at the time when a barrier of some sort existed at Bellows Falls, and this valley was occupied with a lake, while the successive smaller ones, averaging each from ten to twenty feet in height, were formed by the drainage of the lake.

Quite distinct beaches are found on both sides of Williams' River below the bend. The one upon the north side extends back in a depression, hardly sufficient to be called a valley, which must formerly have been a cove, or bay. The south beach is nearly straight, and possibly may be the remnant of an old terrace, very high, which is seen most distinctly at Rockingham village, in the form of two or three rounded hills, rising above the plain.

Bartonsville is located near the lower end of the second basin. Until recently, the highest terrace extended across the valley at that place, showing that there was an obstruction below, which caused the detritus to accumulate and fill up the whole valley, and thus form a basin. The cause of the removal of this terrace will be treated of under Old River Beds. Above Bartonsville there are five very distinct terraces in this basin on the west side, and from three to four on the east side.

The third basin is not so distinct as the others, and the terraces are few, not more than three on either side. Yet the valley expands at the village of Chester, and there is a rocky barrier below, to form the lower limit of the basin. The river is so small here that we should not expect to find a very large amount of detritus, even though on a former continent it had the help of a current from Black River, which diverged from its present course at Proctorsville.

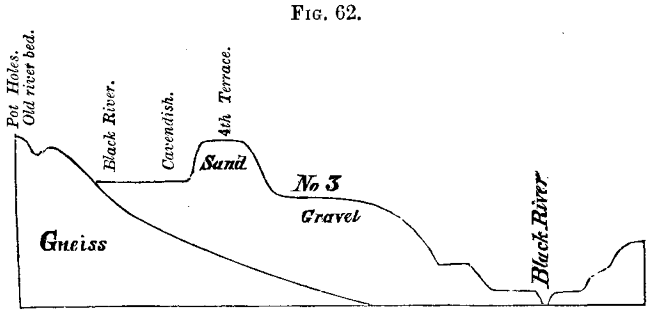
TERRACES ON BLACK RIVER.

Black River rises in Plymouth, and after passing through Ludlow, Cavendish and Weathersfield, empties into the Connecticut in Springfield. Though we have not examined all the sections of its route, we are prepared to mention at least five well marked basins upon it, viz.: at Springfield, North Springfield, Cavendish, Ludlow, and the village at Tyson's Furnace, in Plymouth.

The first basin is in Springfield. Upon the Connecticut in this town terraces are very meager, while upon Black River they are quite numerous and extensive, and produce the beautiful site of the village of South Springfield. Between the two villages is a waterfall, which may be regarded as the limit between the two basins. At North Springfield there is a very large terrace (No. 3) which constitutes an extensive plain. It is at the confluence of the present Black River and a small stream from North Chester, upon the latter of which are found some alluvial accumulations. This plain seems to have been formed as a sort of delta by a former course of Black River, when it ran through the gorge in which the Rutland and Burlington Railroad is built, from Cavendish village to North Chester (Gassett's station), whence it flowed to North Springfield. This plain is composed of sand and fine gravel, and extends nearly to Perkinsville. As a further evidence of this old river bed, besides the facts stated in another place, we would present the fact that between Perkinsville and the mouth of Twenty-mile Stream, near Cavendish village, Black River runs over rocks, and leaves scarcely any terrace materials. Whatever loose materials are present, are entirely composed of coarse drift, for the bed of the river is filled with great bowlders, from the size of a pebble to eight or ten feet in diameter. And there are several falls in the river, known as Upper Falls, Lower Falls, &c. Upon a small tributary stream from the north, which passes through Greenbush, there is an unusually large meadow, accompanied by no higher terraces, which extends to Felchville. It lies immediately west of Little Ascutney, and its formation seems to be due to the easily decomposing nature of the rock that once occupied it, rather than to a powerful current. As will be shown elsewhere, this valley coincides with the strike of certain beds of dolomitic limestone; hence we can readily suppose that an unusually large valley would be formed here, considering the size of the stream that may be supposed to have excavated it. Upon the Twenty-mile stream there are in general two terraces, as far as Plymouth, which are represented, though not with accuracy, upon the map, Plate II, and Plate V, Fig. 1.

The third basin, including Cavendish and Proctorsville, is very distinct. The highest terraces may be regarded as *gorge terraces*—so called because the former barrier at the end of the basin compelled the currents to deposit their detritus near and about the entrance to the gorge. If we examine the enlarged map of this basin, Plate V, Fig. 1, we shall find that the gorge is upon the route of the railroad below Cavendish depot, and that an immense amount of terrace materials have been deposited in Cavendish. They are represented upon Fig. 62, where are also seen the present beds of the river, where the section crosses them at Cavendish, near the depot, and at the mouth of Twenty-mile stream, and the old bed of the river as indicated by pot-holes in the rock. No. 4 crosses the valley in the village, forming a high ridge, which is cut through by the road down the river. It is composed of fine and coarse sand. Besides this terrace, there is a great accumulation of sand and gravel, which is mostly placed upon the map as the third terrace, though it is quite irregular. Two smaller terraces intervene between this and the river. But the river, instead of wearing away a passage for itself through these terraces, has worn a circuitous channel through gneiss, its descent for less than a half mile being 185 feet. This interesting locality will be treated of again under the subject of *erosion.*

Fig. 62.

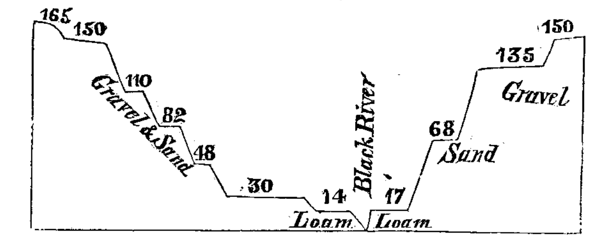


Section of Terraces on Black River at Cavendish.

Following up the river from Cavendish, we see three terraces generally upon both sides, till we reach Proctorsville, where there are four on the north side, and six on the south side, together with an irregular

pile of gravel which blocked up the mouth of the "Proctorsville gulf,"—a deep gorge, the former bed of Black River. They are represented upon Fig. 63, the heights being given by the Aneroid Barometer. This section represents the highest terraces as having the same level, which we should expect, if they had been formed by the stopping up of the valley either at Proctorsville or Cavendish.

Fig. 63.



Terraces on Black River at Proctorsville.

The valley widens at Proctorsville, forming a sub-basin, and it is a beautiful situation for a village. Gov. Fletcher, whose interest in the survey has not ceased with his official duties as Chief Magistrate of the Commonwealth, and one of our geological company, Mr. Hager, have shown their appreciation of Surface Geology by selecting some of the terraces in this sub-basin for the sites of their dwellings.

The fourth basin is at Ludlow. Those who pass through the village on the cars can hardly fail to notice the regularity and beauty of these terraces, as the railroad passes upon the highest of them, showing the whole of the valley and the village below. The highest terraces are very large, and are composed of fine and coarse sand. At Tyson's Furnace one is struck with the evenness of the terraces, though they are not very numerous. On the highest of them are found beds of kaolin and hematite of tertiary age. Like similar beds in other parts of the State, they underlie some accumulations of the alluvial formations. There are very few terraces north of Plymouth Pond. The valley is mostly filled with moraine terraces and glacial moraines. There is a good opportunity to examine the structure of such small terraces as are found upon mountain torrents, at the gold washings east of Plymouth Pond.

TERRACES UPON MILL BROOK.

This stream rises in the northwest part of Reading, and passes through Reading, West Windsor and Windsor, before reaching the Connecticut. It receives the drainage of the north side of Mt. Ascutney, and by combining with the currents of the Connecticut at Windsor village has produced six small terraces on its south bank, on the fifth terrace of Connecticut River. They are very beautiful, and are represented upon Plate IV, Fig. 3, which has already been noticed when speaking of the terraces on the Connecticut at Windsor.

If we were to dignify the different deposits of terraces upon Mill Brook as basins, we should mention at least two; first, the Windsor basin, which contains all the terraces that occur upon the river, for at least two miles from Windsor court-house; secondly, the Brownsville basin, which commences with the barrier of rock limiting the first basin, and extends a little way beyond Brownsville in West Windsor. There are generally about three terraces of coarse and fine gravel on both sides of the stream, over the whole of the basin; but for ten miles of the distance between Brownsville and Windsor there are no terraces. Beyond Brownsville we have not examined the terraces, and presume that they do not deserve notice. We shall pass by many other smaller tributaries of the Connecticut for similar reasons.

Before reaching the Otta Quechee, a stream joins the Connecticut at Hartland, upon which there is a small, very well marked basin, in the village of Hartland. Its position may be seen upon the Map of Connecticut River, Plate III, where its first terrace is represented as the fourth terrace of the Connecticut, and is somewhat spoon-shaped. Its second terrace is No. 5 of the latter river, and it is composed of coarse gravel.

It may be well to mention here, that the numerous small tributaries of the Connecticut, many of which are of too little consequence to be placed upon the map, have been of great service in the formation of the large lateral terraces of the principal stream. At their mouths, it is almost always the case that the larger terraces are better developed than elsewhere, and when traveling along the banks of the Connecticut, we have often been interested to notice how easily the position of small streams could be learned by this superior development of the terraces at their mouths, which are thus really *latero-delta* terraces. Were we to consider every occasional brook that springs into active existence at the close of each storm of rain, as worthy of notice in the formation of the large lateral terraces, the latter would all be a combination of lateral and delta terraces. For they were formed by the combination of these two forces, the current of the main stream, and the delta deposits of the smaller streams and occasional brooks.

TERRACES UPON OTTA QUECHEE RIVER AND WHITE RIVER.

The Otta Quechee River rises in Sherburne, passes through Bridgewater, Woodstock, Hartford, and unites with the Connecticut at North Hartland. Above Woodstock Court House, as the map shows, the traces of a former glacier mostly occupy the valley, in the form of embossed rocks and moraines. At the village of Woodstock there is quite an expansion of the first terrace, with perhaps one or two others: but hardly of sufficient account to be a very well marked basin. At Quechee village, however, there is a very distinct basin. Southeast of the village, near Dewey's Factory, on the southeast side of the stream, there are seven very perfect terraces, and four upon the opposite side. They are perhaps gorge terraces, as they are at the mouth of quite an extensive gorge and waterfall. In this very interesting region, there is an old bed of the river upon the east side. But no one of the Geological corps has examined this region for terrace phenomena, and therefore we shall be unable to state definitely any facts concerning this region. Between Woodstock and Quechee village we know, however, that there are scarcely any terraces, and we have presumed that between Dewey's Factory and the mouth of the Otta Quechee, the banks are mostly rocky, as both ends are rocky. If so, we might look for some other outlet for this river, either above, or below, as it is generally the case with rivers, that terraces are the best developed near their mouths, and that unless the existing stream shows them, they are to be found upon some former course of the river. The Connecticut is a fine example of this statement, as before given. We should be unwilling to suggest any former course of the Otta Quechee, as we are unacquainted with the face of the adjoining country.

This river has, however, at its point of union with the Connecticut, modified the terraces of the latter stream, as the section in Fig. 58 will show. It has also carried away a large portion of the Connecticut's terraces at North Hartland. The river falls over strata of clay slate near its mouth, at least four times, and the amount of fall is from sixty to seventy feet. Near the town line between Bridgewater and Sherburne, the Otta Quechee passes through a gorge, which is cut across a high range of hills. This range is nearly straight, with a north and south course, and between Stockbridge and Ludlow there is no interruption in it except this gorge. The valley west of this range is unusually prominent, although in the north part of Plymouth it forms a dividing ridge between waters which flow into Black River and into Otta Quechee River. This watershed is only 320 feet above the Otta Quechee, at the entrance of the gorge. Hence, we have supposed that instead of crossing this range, the waters of the Otta Quechee formerly flowed through this prominent valley into Black River.

There has been a blocking up of the gorge on the Bridgewater line at some time during the alluvial period: for the accumulations of rather coarse materials at its head in Sherburne are very great. One of these hills of modified drift arrests attention by its striking appearance. It occupies the middle of the valley like an island in a lake, and is probably an outlier. Probably the bottom of this valley was filled a hundred feet or more with detritus, when the river flowed into Black River instead of coming to Woodstock; and it is likely that this outlier is only a remnant of that deposit. There are some falls in the Otta Quechee in this gorge, of about 30 feet altitude.

We come next to White River, which is a large stream. The principal branch arises from the Green Mountains in Hancock, Rochester and Pittsfield, passes through Stockbridge to Bethel, where it joins the other branch coming down from Roxbury; both then follow the route of the Vermont Central Railroad to White River Junction. The upper part of the west branch is filled with the marks of former glaciers, viz., in Hancock and Rochester. No terraces of any account are found upon the north branch between Roxbury and Randolph. At the latter place a stream from Brookfield, passing over a route formerly contemplated for the Vermont Central Railroad, joins this north branch, and seems to have been the chief producer of the terraces. It is somewhat difficult to state the precise number of basins upon White River, as they are comparatively small, and quite numerous.

We will specify ten basins upon the principal part of White River, which we think are well defined. The hurry of our observations did not permit us to delineate other smaller basins, which probably exist; and in fact it was chiefly by an examination of all the notes collected during the survey, that the arrangement of the terraces in basins was ascertained to exist. Hence it would have been very easy for the observer to have overlooked some of the smaller basins, when he was not aware that the terraces were thus disposed in nature.

The first basin belongs to the ninth basin of the Connecticut, which extends from Windsor to Norwich. It is quite short, extending only from White River Junction to a short distance west of White River village. Yet the terraces are finely developed, especially where White River unites with the Connecticut, there being five terraces on the south side—the highest of which is composed of sand, and its summit is 209 feet above the Connecticut at the Railroad Bridge over White River—and four upon the north side.

The second basin extends from White River village, nearly to West Hartford, and is well lined with terraces upon both sides, their number being nowhere less than three, and never exceeding seven. Yet the number varies for every half mile. The valley varies from a quarter of a mile to a mile in width.

The third basin extends from a rocky barrier at West Hartford, to a similar barrier, well marked, a mile southeast of Sharon. The terraces are less numerous upon it than in the second, the number never exceeding five, and there being often only No. 4 present.

The fourth basin extends to South Royalton, and is limited like the others by a rocky barrier. Near Sharon village the terraces are very beautiful, and in one place on the south side, No. 3 is unusually extensive, reaching to the river and passing by the terraces to the southeast, like a tongue. This large terrace seems to have been brought down by a branch of White River from the south.

The fifth basin extends to Bethel and somewhat farther, and is characterized by very distinct terraces, of which there are generally four upon each side of the valley. The limit between this and the next basin is not very well ascertained; but we can say that the village of Randolph is in the sixth basin. So beautifully marked are the terraces in Randolph, that the traveler from the north on the railroad, who inspects the country as he passes, is at once struck by the change of the scenery at this point, for he suddenly comes from a region utterly devoid of terraces into their very midst. We were unable to follow up the branch towards Brookfield to examine its terraces, but judge that they are numerous upon it, and that formerly the stream must have been larger than it is at present, to have formed them.

Returning now to Bethel, we follow the west branch to Hancock, or more properly White River itself. Bethel was said to be in the fifth basin. This extends a mile or two west of the village on this branch. At Gaysville we find ourselves upon another basin, the sixth from White River Junction, which is not rich in terraces, there being at Gaysville two terraces on the north side and three on the south side. In Stockbridge, at the Hotel, are very high terraces, but few in number, which are considered as belonging to the seventh basin. Upon the eighth basin, in Stockbridge, at the southern limit of the basin, No. 4 blocks up the valley to a depth of some 300 feet, much in the manner of a terminal moraine. The chief village in Stockbridge is located upon it. In the south part of Rochester there is a similar accumulation of material. But this is composed of coarse water-worn materials, and may perhaps be a terminal moraine of the great glacier that once slid down this valley from Hancock and Rochester. The fact that it is at the mouth of a small stream from the east, may show that some of the mass has been transported from the east, and also that this current has been an agency to modify the materials of the moraine. Other tributary streams in the vicinity have brought in detritus to the principal valley, and formed delta terraces, but they are all very small when compared with this moraine, and they do not extend across the whole valley like this.

Some very pretty terraces are found at the village of Rochester, which we have considered as constituting a separate basin. Above this point we have not thought it desirable to establish distinct basins, as terraces are only found occasionally, and, like the west branch of the river in Rochester, the evidences of former glacial action have taken the place of terraces. We noticed several very large accumulations, especially in Hancock, which will be described in the proper place as moraines.

These terraces upon White River will be found delineated upon the general map of Surface Geology,

Plate II. We should have been glad to have given an enlarged map of the Surface Geology of White River.

Between White River Junction and Barnet we have very few notes upon the Surface Geology of the tributary streams of the Connecticut. We will mention, however, all the facts in our possession. In Norwich there is a small stream from the northwest, upon which the village is built. Near the sources of this stream there are interesting beaches and moraine terraces, and at the village of Norwich there is at least one distinct terrace, namely, the plain upon which Norwich is built. It is sandy and quite extensive.

The Ompompanoosuc River has a few well marked terraces near its mouth, and probably they extend in perfection for several miles along its banks. We crossed the river in the west part of Thetford, but did not observe any facts worthy of mention.

Wait's River promises finely for terraces. A glimpse of a few in Bradford is the only view we have been permitted to have of them, except a few in East Corinth. We regret much that we were unable to explore them.

Wells River is another very promising stream, but we have been unable to examine its terraces.

TERRACES ON PASSUMPSIC RIVER.

We are now approaching that part of Vermont where the accumulation of water-worn materials is very great. The northeastern counties are almost entirely covered up with alluvium, in the form of terraces, moraine terraces, sea beaches and sea bottoms. Their thickness is greater than in other parts of the State, and their distribution over the entire surface is much greater; so much so, in fact, that in many places it as difficult to ascertain what kind of rock occurs below the surface accumulations. The upper part of the Passumpsic River is in the midst of such accumulations. The materials are often coarse, but are very abundant, as the traveler upon the railroad from St. Johnsbury to Barton will easily see. They are to be ascribed to some general causes for their formation, rather than to rivers, and it is a matter of regret that our researches among them have been so limited.

Notwithstanding the size and number of terraces on the Passumpsic, we will not at present venture to specify more than two or three basins, so connected with one another are all the lateral terraces. The first of them extends from the mouth of the river in Barnet to the northwest corner of the town of Waterford, near the Passumpsic station, on the Connecticut and Passumpsic Rivers Railroad, and is about four miles in length. The river passes through a narrow valley in Barnet, a kind of gorge, with no terraces. Then there may be seen narrow terraces, which at Passumpsic expand and form a beautiful basin. The fourth terrace on the west side of the river passes into the next basin, which is embraced in the towns of St. Johnsbury and Lyndon. Upon this high terrace is the beautiful village of St. Johnsbury, designated as St. Johnsbury Plain. A. D. Hager states that the base of the terraces at St. Johnsbury is composed of clay. The same terrace occurs on both sides of the valley beyond Lyndon, and the lower terraces may be seen at intervals. At the principal village in Lyndon a remarkably high terrace exists, which may have formerly extended across the valley to form the end of a basin. Its lower strata are clayey, and are remarkably folded and curved. West of this terrace the level is lower, and here is the course of an old bed of a tributary stream from the west. At the upper village of Lyndon the first terrace is about a mile wide, and the amount of terrace materials adjoining it is very great, and most of the materials are sand and fine gravel. Every tributary stream from either side has its large terraces to correspond with those of the Passumpsic; and it is a characteristic of these terraces, in distinction from those on the Connecticut and its other tributaries, that while they are very large, their number is small: in no case did the number exceed five, while on the latter streams the number often amounted to seven, eight and ten.

The third basin, whose limits are not marked, comprises that part of the Passumpsic River (east branch) which flows through the territory of Burke. At the village of East Burke, several distinct terraces were observed, and near it there are four on the west side and No. 1 and No. 4 on the east side. Above East Burke the valley rises, so that its bottom appears like a terrace, with its steep slope crossing the valley at right angles; and there are indistinct terraces upon its sides. It seems to be too wide a valley to correspond

with the size of the river, and may have been formed by some currents of water from foreign sources at an early date. We understand that this valley extends to Island Pond, at about the same elevation. If so it may throw some light upon the existence of some former river.

Upon the west fork of the Passumpsic above Lyndon, deposits of sand and gravel, similar to those at Lyndon, are found along its whole course. Many interesting sections might be taken in the excavations made by the railroad, that would illustrate various phases of stratification, as well as the relations of the different kinds of alluvial deposits to one another. Sections similar to one represented in Fig. 41 are very common, and they may perhaps show that a large part of former deposits of sand and gravel have been worn away.

Concerning the tributaries of Connecticut River in Essex county, we can say nothing. This region is not traversed by roads, and has not been visited with reference to this point. We should presume, however, that terraces occur on every tributary of considerable size, especially upon Nulhegan River, and the outlet of the two Leach Ponds in Averill and Canaan. Indeed, upon the latter, at its mouth, we saw five or six distinct terraces running up the valley, but could not examine them above the village of Canaan.

TERRACES IN THE SOUTHWESTERN PART OF VERMONT.

Deerfield River waters seven towns in Windham and Bennington counties, and empties into the Connecticut in Massachusetts. Its valley is noted for its remarkably fine terraces, in Massachusetts; but in Vermont the action of drift, and of glacial agency at a recent date, has not facilitated the formation of terraces, because it has filled the valley with very coarse materials, which water has not been able to act upon effectually. Along the Deerfield River in Readsboro, Whitingham and Wilmington, a few small terraces of gravel are frequently seen, and sometimes they form a marked feature, as at Readsboro City. Upon the west branch remnants of high terraces are occasionally seen, and near the summit level of the Green Mountains there is a distinct basin of small size at Hartwellville. There seems to have been a barrier below the village which has been removed comparatively recently, which was an essential element in their production. This plain or meadow is about 1200 feet above the ocean.

Following up the main stream of Deerfield River to Searsburg, the terraces give place to huge blocks and bowlders of mica schist, which continue to Somerset. Upon the Wilmington branch the terraces are made of gravel, and are of small size; and scanty numbers of them may be seen as far as West Dover and East Somerset. Yet they are sufficiently large to have fine farms located upon them.

Passing to Stamford, a few terraces show themselves upon the north branch of Hoosac River, and by the time that we arrive at the south State line, the valley has become quite wide, and contains tertiary deposits of kaolin clay and hematite, below the alluvium.

We find the same Hoosac River again at Pownal, where it is much larger, and the alluvial accumulations upon its banks much more interesting. In Massachusetts the river passed around Oak Hill in Clarksburg, to Williamstown; and from there to Vermont, through a very deep valley, and intensely interesting geological region. The following facts respecting the surface geology of Hoosac River in Pownal, have been derived from the notes of the Principal of the Survey.

As soon as the Hoosac River enters Vermont it makes a bend of more than a right angle, within and without which are grouped several terraces. There are five on the north side, and the same number are found, except some local variations, through the whole of Pownal. At this bend they are not all placed in order, but are found near each other. The first terrace on the north side is scarcely six feet above the water, and is not extensive; the second is 16 feet above the river, or ten feet high, and is more extended than the first; the third is 20 feet high, or 36 feet above the river. All these are composed of loam and sand. The fourth terrace is 102 feet above the river at its inner edge; the fifth is 307 feet above the river. The two last are remarkable, not so much for their great height, as for their slope towards the bottom of the valley, and their composition. The slope is from 6° to 10°, of which slope the three lower terraces partake somewhat. And the highest terraces are partly composed of consolidated sand and pebbles, at least 100 feet thick. The conglomerate consists of pebbles of quartz, micaceous and clay slates, from three to four inches in diameter, down to coarse sand, (see Nos. 1-92 and 1-93.)

The cement is carbonate of lime, derived from the limestone in the neighborhood, infiltrated into the gravel in a state of solution, and uniformly diffused through the mass. This cement is discovered only by the application of an acid, when a brisk effervescence ensues. The stratification of this solid mass is as distinct as that of any of the older consolidated rocks.

The dip of this rock is explained by original deposition. The valley is quite narrow, and must have been very deep when the conglomerate, which is the lowest part of the terraces, was forming; consequently the materials that were brought from the northwest were deposited on a slope, like the loads of gravel, etc., added to the steep slope of a railroad embankment. Perhaps, also, the reason why only part of the terrace is consolidated, is due to the character of the underlying rock. The hill back of the terrace is micaceous schist underlaid by limestone. As the limestone is in the lowest part of the valley — if the cement was obtained from this rock, in place, after the deposition of the terrace, we should expect that its influence would extend only so far above the level of the river as the rock extended. The exact thickness of the limestone at this point has not been ascertained, and perhaps we might apply the converse of our proposition to determining the height of the limestone; if so, the suggestion would serve two important purposes.

Beyond this bend in the river, the valley widens, and with it the first terrace, until there is an extensive plain at South and North Pownal. As Hoosac River is mostly located in other states we have not traced out the number of basins upon it, but without hesitation we can say that there is at least one distinct basin of terraces upon it in Vermont.

Going to the north, we next come to the Waloomsac River, which rises in Pownal, passes through Bennington and unites with the Hoosac River near Eagle Bridge, in New York. At North Bennington, the valley of the Waloomsac is narrow, owing to the presence of silicious limestone, which has been cut through with difficulty. A small terrace is seen, which corresponds to No. 2. Numerous small bowlders of quartz rock are seen, which have been brought from the east part of Bennington and Woodford by the action of the river. They are all water-worn, and furnish an illustration of the character of modified drift, when compared with unmodified drift. In East Bennington, or in the center of the territory of the town, the meadow of this river spreads out and is bounded on its edges by a second terrace. It is the plain upon which East Bennington is built, and both terraces together constitute a basin.

The main stream continues to Barbar Pond in Pownal; the upper portion of its course exhibiting many large moraine terraces. The Woodford branch passes through the quartz range directly east from Bennington, and has its banks and rough terraces composed of drift bowlders scarcely modified, and underlaid by tertiary deposits. Like the materials at the foot of the Green Mountain range from Connecticut to Starksboro, Vt., so here, bowlders of the metamorphic quartz rock are grievously abundant.

A small tributary creek of the Waloomsac at North Bennington, which follows the Western Vermont Railroad to Shaftsbury, has finer terraces upon it than any other branch. They amount to four, north of South Shaftsbury, and are succeeded by an old sea beach or sea bottom, at the summit level at Shaftsbury Center. A large part of the coarse gravel constituting the first and second terraces, between North Bennington and South Shaftsbury is consolidated, like that at Pownal. We suppose the cementing substance to be the same — carbonate of lime — although there is a great amount of the peroxyd of iron present, which gives its characteristic yellowish color to the whole mass. We presume from these two cases of consolidation, that in the limestone region west of the Green Mountains, especially when near the tertiary beds of hematite, consolidated masses of gravel and sand are common.

Passing over the sea beach in Shaftsbury Center at the Railroad station we see a very high terrace, composed mostly of sand, in the middle of the valley, forming a sort of a ridge. It slopes to the north four or five degrees, and may be followed to Arlington Center, where it caps the hill east of the railroad. It seems to us rather to have been formed by some other agency than any existing stream — either some larger stream or the ocean, as it is continuous from the old sea beach in Shaftsbury to Arlington. We have marked it on the map as the fourth terrace on the Battenkill River at Arlington, continuing south to North Shaftsbury, and it certainly is the fourth terrace at Arlington. With this so called terrace, are sometimes associated moraine terraces.

Upon Roaring Branch (a tributary of the Battenkill at Arlington), in E. Arlington and Sunderland, there are no distinct terraces, but simply an irregular mass of bowlders and soil east of Arlington line.— The rest of its course passes over rocks.

But at Arlington there is a distinct basin shown, which extends from this village up the Battenkill a considerable distance to the north, and is limited west of the village by a rocky barrier. On the southeast and east sides, at the village, there are four terraces; the upper one composed of fine materials, the lowest of loam and peat, and the intervening ones of fine and coarse gravel. The meadow extends south a mile, lying immediately east of West, Canfield & Co.'s marble quarry. On the northwest side of the river we also saw four terraces, of which the highest, perhaps, ought to be called a moraine terrace. The elevations are conical and tortuous, and their summits are about 300 feet above the river.

Passing down the Battenkill, at first the narrow valley between the two mountains that rise above it over a thousand feet on either side, is devoid of terraces. They appear at length in great force at the confluence of Greene River with the Battenkill at West Arlington. There are four on each side of Greene River, extending a mile or two north. On the Battenkill there is a very high terrace, No. 4, whose height was measured by the Principal, and its summit was found to be 349 feet above the river at its base. But one higher terrace has been measured in Vermont.

Several other interesting terraces were found in this basin. Near the west line of the State there is a rocky barrier. Passing into New York, the terraces again display themselves in rich profusion. They are not as high as the one described, but they are numerous, and as distinct as if they had been carefully constructed by the best engineers. This was in the village of East Salem, N. Y.

Returning into Vermont and passing up the Battenkill to Dorset through Manchester, we find five exhibitions of terraces and moraine terraces. The valley itself is the most interesting of any in the State. It is long, very deep, with steep sides and high mountains, shutting out all distant views. The Green Mountains are upon the east, and the Taconic range upon the west, both averaging nearly 3000 feet in height. And the whole of this great valley seems to have been eroded by aqueous agencies: most of it long before the existence of the Drift. The alluvial deposits, though on a large scale, are comparatively insignificant. The interest the geologist takes in this region is not confined to the alluvium.

The general character of the alluvium along the Battenkill in this valley consists in a nearly constant meadow, generally narrow, but occasionally much expanded, a very high terrace (No. 4) upon both sides, which either merges into, or rests upon moraine terraces. At intervals, Nos. 2 and 3 of the terraces intervene. Away from the vicinity of the river the deposits are quite thin, although the rock is not prominent. This is a general characteristic of all limestone regions.

In the northwest corner of Sunderland, at the depot, there is a narrow meadow, with Nos. 1 and 4 upon the west, and only No. 4 upon the east side; but moraine terraces occur behind both the No. 4 terraces. No. 4 is wanting in a portion of the southern part of Manchester, but near the Cemetery, south of the village of Manchester, the terraces are the same as in Sunderland. At Factory Point the meadow increases in size, and is nearly a mile in its greatest width. It is mostly surrounded by terrace No. 4. The lower terraces show themselves more prominently between Factory Point and East Dorset. Our impression is, also, that the terraces in Dorset are more regular in their proportions than in Manchester.

In East Dorset there are three distinct terraces on each side of the river. At the summit level near Dorset Pond, which is the source of the Battenkill River and Otter Creek, there are accumulations of moraine terraces, or perhaps gorge terraces.

Passing up the west branch of the Battenkill, from Factory Point in Manchester, we find from two to four terraces along its banks, as far as its source, in Dorset. Thus we think we can point to four basins on the Battenkill, in East Salem, N. Y., West Arlington, Arlington, Manchester, and Dorset. There are doubtless other basins between Salem and the Hudson River.

A branch of the Battenkill arises in Rupert. At Rupert village the first terrace is of considerable extent, and is surrounded by only one terrace, No. 2, which also extends a mile east of Rupert. The same terrace is found upon Black Creek in the northwest part of Rupert, another tributary of the Battenkill.

Dorset village is 1023 feet above the ocean, and is on the summit level of streams emptying into Hudson River and Lake Champlain. The level space is extensive, and the accumulations upon it may have been brought down partly from Dorset Mountain, and partly collected by the action of former oceanic waves.—Pawlet River rises on Dorset Mountain, and has formed terraces for two miles east of Dorset, two or three in number on each side, which are rather small; although the mountains shoot up above them 2000 feet. As will be shown in the chapter on erosions, a mass of rock 2000 feet thick has been removed from this valley, since the upheaval of the mountain. Part of this eroded detritus has been used to form the terraces on Pawlet River, which are remarkably perfect from Dorset to near its mouth at Whitehall, N. Y.—Near the west line of Dorset the meadow expands, and is shaped like an equilateral spherical triangle, as its outline appears when protracted on a plane surface. It is surrounded with distinct terraces, four on the northeast side, and three on the other sides. As the valley contracts at East Rupert, and a few ledges show themselves, the terraces on this river in Dorset probably constitute a separate basin. We were unable to examine this river elsewhere, except at its mouth, and can say but little respecting its surface geology. The Principal of the survey saw the terraces in the town of Pawlet on this river, and says that at the village of Algiers, where Flower Creek joins Pawlet River, the view of the terraces is unusually instructive, and would afford an excellent sketch to illustrate Vermont scenery. Concerning the alluvial deposits on Pawlet River in New York, Prof. Mather in his Report says, that there is an extensive patch of quaternary deposits south and southeast of Whitehall, between Pawlet River and Wood Creek.

TERRACES ON POULTNEY RIVER AND ITS TRIBUTARIES.

On Poultney River also there are very fine terraces, which have not been examined except at one or two points. For four miles north of its junction with Lake Champlain at Whitehall, there are two small terraces on the Vermont side in West Haven, and scarcely any deposits on the east side in Whitehall.—The terraces are composed of two kinds of clay; the lowest part, which at rather high water was found only three or four feet above the water level, is blue; the remainder is reddish, extending perhaps twenty feet in height above the river, in a terrace form. Near the mouth of Hubbardton River, the clay corresponds more with the general character of the Champlain clays.

At the north part of Fair Haven there is a terrace composed of loam and blue clay, 100 feet high on the east side of the river, and small low terraces of clay on the opposite side. It is at a place to be described, where the river changed its course in 1783.

Prof. Mather also speaks of the quaternary on Poultney River: "It extends," he says, "from Hampton, N. Y., and West Poultney, Vt., on the Poultney River, southwest to Granville, where it spreads into broad plains;" and that these plains "are at the junction of the valleys of Poultney and Pawlet Rivers with the eastern channel of the Champlain and Hudson valleys."

At the village of West Poultney the meadow is very large, being more than a mile in width. Terrace No. 4 bounds the meadow upon the south side, and Nos. 3 and 4 upon the north side. Further north, No. 2 is inserted between No. 3 and the river. Upon Lewis Brook, in the north part of the town, Nos. 3 and 4 are developed more prominently than any other number. There is manifestly a former bed of Lewis Brook to West Poultney along the route of the Rutland and Washington Railroad, and probably of Castleton River to Poultney. The railroad passes over thick beds of sand and pure gravel over the whole distance.

The rest of Poultney River has not been examined. We know from general sources that the meadows upon it are very extensive and fertile. We will add a few words respecting some of its tributaries. On Codman's Creek, in West Haven, there are two terraces throughout its whole extent, the highest being generally on a level with the top of the Champlain clays.

Hubbardton River has three terraces upon its banks, pretty regularly through West Haven to Benson village. As the river rises in a rocky region, it has transported sand and gravel to form its terraces. But some of them are formed of clay.

There is a distinct basin of terraces on Castleton River, embracing the villages of Castleton and Castleton Corners. At these villages the second terrace is remarkably broad. It is composed at the upper part of sand, and upon this site the villages are built. Occasionally a third terrace is seen upon Castleton

River, before reaching Ira, where the river has cut through the Taconic range of mountains. In this cut the accumulations are mostly in the form of moraine terraces. In West Rutland, near the celebrated marble quarries, this stream runs through a meadow, quite low and marshy, and there are no other terraces.

It seems remarkable that this small stream should rise east of a range of mountains 1000 feet high, and after flowing to the south for seven miles, suddenly bend its course at right angles and cut through the mountain; especially when an obstruction of a few feet in the gorge would divert the stream southeast to Otter Creek at Rutland. As this gorge runs east and west, contrary to the most usual direction of excavated valleys in the State, and as it is in the region of curious and gigantic disturbances of the underlying strata, we can but suspect that this valley through Ira has been formed in some other way than by erosion. Perhaps it originated in a fault among the metamorphic schists.

TERRACES UPON OTTER CREEK AND ITS TRIBUTARIES.

Otter Creek rises in Dorset from Dorset Pond, which is also the source of the Battenkill, passes through the whole of Rutland and Addison counties, and discharges its waters into Lake Champlain, in North Ferrisburgh. The lower part of its course is over the Champlain clays, where its rate of descent is very small, except at an occasional fall over ledges of rock. The upper part of its course is over an undulating country, near the western limit of the quartz formation, and its whole course is over calcareous rocks, except when it crosses a range of quartz rock in Rutland. We will describe its terraces, commencing at its source, contrary to our usual order of description, and speaking of the tributaries as we find them in our descent.

The valley in which Dorset Pond is situated is remarkable for its narrowness and depth. One would hardly imagine that upon such a low level would be found the water-shed of waters flowing to Long Island Sound in one direction, and to the Gulf of St. Lawrence in another. Unusually large also are the moraine terraces, or more properly the gorge terraces at the source of Otter Creek.

In the town of Dorset, except a narrow meadow, there is but one short terrace belonging to Otter Creek, and that is No. 4 upon the west side. In Mt. Tabor and Danby, there are scarcely any terraces, except at their north parts. Moraine terraces take their place. In the northeast corner of Danby, Nos. 1, 2 and 5 are well developed. And to this point there comes an old river bed, on the east side of Otter Creek, from a small river in the south part of Wallingford. Between this bed and the creek in Wallingford, Nos. 1, 2 and 4 are developed. Just above South Wallingford, ledges of rock form the banks of the creek, which may be considered as the boundary between two basins of terraces. Through the rest of Wallingford it is rare to see any terrace of much account, except the meadow. There is terrace No. 3 upon the west side at South Wallingford, and a short No. 4 a mile north, on the opposite side; and there are moraine terraces upon both sides of the creek from North Wallingford to the village of Clarendon. In Wallingford the valley is narrow and quite deep. It seems to have been formed by the ready decomposition of the rock,—for the belt of limestone upon which the creek runs, is often not more than a fourth of a mile wide,—and the adjacent rocks are ore of the hardest of all rocks, namely, quartz rock.

The valley is much wider at the village of Clarendon. * Mill River here empties into Otter Creek. This river rises in Mt. Holly, following the route of the Rutland and Burlington Railroad to the east line of Clarendon at Cuttingsville, when it turns west to Otter Creek. Between East Wallingford and Cuttingsville large terraces of gravel and sand are common, especially a large amount of moraine terraces. At Cuttingsville it cuts through a high ridge of rock, forming a deep gorge, which has not been visited by any member of the geological corps, though it is in full sight from the railroad.

Between the villages of Clarendon and Rutland (Depot), we have marked on the map no terraces except the first and second. These are unusually broad. No. 2 is traversed by two railroads in Rutland, and is more than a mile in width. The great Railroad Depot in Rutland is situated upon the second terrace. East of the village the coarse unmodified drift abounds. Upon East Creek, which joins Otter Creek near the depot, two terraces may be seen upon both sides, even to the northeast corner of the town. Two

* We use the names employed by the inhabitants to designate these streams, although it seems very incongruous to say that Mill *River* empties into Otter *Creek*.

branches of East Creek, both having the same name as their united waters, come together in this corner of Rutland, the one from Chittenden, and the other from Mendon. Very fine terraces are found upon the Mendon branch for half a mile above the junction, but they will not compare for their number and symmetry with those upon the Chittenden branch in Rutland and Pittsford. The terraces are formed out of an immense amount of detritus brought down from the mountains by these two streams. Terraces are found upon the Chittenden branch worthy of notice, beyond South Chittenden; but much of their materials consists of large bowlders of quartz rock. The first terrace is quite broad a mile below the village of South Chittenden.

The very serpentine course of Otter Creek, both above and below Rutland, is due to the loamy character of the meadow. All sluggish streams passing through fine materials are characterized by a meandering course.

West of Rutland Depot accumulations of coarse gravel press close upon the river, which are not distinct terraces. Farther to the north the creek passes over rocks, finally tumbling down a precipice at Sutherland's Falls. From this point commences a meadow often over two miles wide, extending to the south part of Middlebury. Here it is very narrow, and in this condition extends to Vergennes, where it is interrupted by a ledge of rocks; after which it continues uninterruptedly to the lake, and at its mouth a delta is forming, consisting now of low marshy land.

A second terrace is continuous from Sutherland's Falls, to the lake along the banks of Otter Creek From Weybridge to the lake, what we have called the second terrace is of the same general level as the Champlain clays. Still it has the form of a terrace, and it is convenient to call it one, although we suspect that it was formed by the creek—only in this sense, that the creek cut a passage for itself in an oceanic deposit. The same remark will apply to all the small streams in the Champlain clays, and the map shows that nearly all of them have only two terraces, the meadow, and the border of the old oceanic deposit.

Tinmouth River, emptying into Otter Creek near Center Rutland, exhibits very few terraces. From its source in Danby to North Tinmouth the meadow is quite narrow, and there is only one terrace worthy of notice, which is near the north line of the town. In Clarendon its valley is generally quite narrow. As soon as it enters Rutland the meadow begins to expand, and for a part of the way terrace No. 2 may be seen at its side. Rarely a level-topped hill may be mistaken for a terrace upon this stream, as in the north part of Tinmouth. It consists of horizontal strata of limestone, capped by a few feet of decomposed rock. There is a high hill of modified drift, perhaps a terrace, immediately east of West Rutland Church. One end of it we estimate to be 50 and the other 100 feet high. The church is located upon the second terrace.

The terraces on Furnace River in Pittsford are well developed. At Pittsford Mills there are four terraces on the east side and three on the west side, all very distinct. These continue, with an occasional interruption, beyond Hitchcockville to the Furnace village, three miles from the mills. Below the Furnace there are four terraces upon both sides of the river, of which the highest is of tertiary age. Furnace River turns abruptly to the east near the Furnace. Upon the north side of this turn there are six terraces, rising one above another, whose production was facilitated by a small tributary from the north.

At the furnace there commences a narrow deep gorge, but not of great length. Between this gorge and North Chittenden there is a prodigious amount of terrace materials in the form of terraces and moraine terraces. At the upper end of the gorge there may be seen four terraces upon each side of the river, some of them remarkably distinct, and the highest is far above the gorge. Nos. 1, 2 and 3, though very distinct, are unusually short: hence they appear and disappear so rapidly in passing along the river, that it is impossible to map them upon so small a map as Plate II. But No. 4 or the highest terrace is generally constant. We traced it upon both sides of the river as far as a curious tower of limestone, nearly a mile and a half above North Chittenden. The village at North Chittenden is located in a pretty basin hollowed out of the highest terrace. Most of the terrace materials in Chittenden are very coarse, as is generally the case upon rapid streams near high mountains.

Upon Sugar Hollow Brook, a tributary of Furnace River at the village of Pittsford, there is a fine basin of terraces about two miles north of the village. The scenery in the vicinity is quite picturesque. Between this basin and the village the stream passes through a rocky gorge.

A very distinct beach continues to Brandon, at Forestdale, from Pittsford, and at its lower part the materials are fine sand. Another *Mill River* joins Otter Creek below Brandon village, upon which there are three terraces near Forestdale, and two in Brandon. The village is situated upon an expanded terrace, and, like everything in Brandon, this terrace is well formed and attractive to the eye.

There are two terraces upon the outlet of Lake Dunmore, Leicester River, as far as the village of Salisbury. The meadow of Otter Creek is wider at the mouth of this stream, than at any other place in its course, and much of it on the west side is almost worthless from its marshy condition. An unusually wide meadow runs up Leicester River from the creek, but is soon narrowed.

Two pretty terrraces pass up Middlebury River to the east part of the town; and at the village of East Middlebury the meadow becomes an extensive plain. Above the second terrace, on the west side, the clays rise gradually until they reach the top of a low hill east of Middlebury Court House.

The north branch of New Haven River rises in the south part of Starksboro, and unites with the south branch from Lincoln in the east part of Bristol. Upon so much of the north branch as flows through Bristol, there is an immense terrace No. 4, besides the meadow, on both sides of the valley. The south branch may have a few terraces upon its banks in Lincoln, but between the village and its union with the north branch the banks are rocky, and the narrow valley is filled with enormous bowlders of quartz rock. The same is the character of New Haven River as far as the village of Bristol. There it has emerged from the mountains, and has deposited its detritus in the form of terraces. The village is situated upon a high extensive terrace, No. 4, composed of sand and gravel, underlaid by tertiary deposits. This terrace extends a great distance northerly towards Monkton. Half a mile west of the village, four terraces show themselves upon the north side of the river in regular succession. Of these, No. 3 is twelve rods wide, and No. 2 is of little account. Upon the opposite side of the river, none of these terraces may be seen except Nos. 1 and 4. Between this point and the mouth of New Haven River there are in general only two terraces, which may perhaps correspond to Nos. 1 and 4. A few years ago there was a very destructive freshet upon this river, of which an account was published in Thompson's Vermont, and also in a small book written by one of the principal sufferers.

The Lemonfare River, rising in Orwell and joining Otter Creek at Weybridge; Dead Creek and its branches, in the towns of Ferrisburg, Panton, Addison and Bridport, and Little Otter Creek in Ferrisburg, Monkton and New Haven, are all situated upon the Champlain clays, and have therefore done little else than excavate a passage for their first terraces over their whole extent. Yet they are marked as having two terraces, on the map, for reasons specified above. The latter stream is not a tributary of Otter Creek, but discharges its waters into Lake Champlain.

TERRACES UPON LEWIS CREEK AND LAPLOP RIVER.

Lewis Creek rises in Starksboro on the east side of the quartz ridge, passes through the northeast corner of Monkton, the southern limits of Hinesburg and Charlotte, finally uniting with Lake Champlain in Ferrisburg. Until we reach some mills east of the village of North Ferrisburg, in ascending the stream, this creek seems to have been so sluggish as to have merely cut a channel for itself through the clays. At the mills it has formed four terraces on the north side, and then upon the south side, for here it emerges from a somewhat rocky bed. In Charlotte, where the current is swifter, we saw three terraces on each side of a narrow valley. The valley grows wider in Hinesburg, and in the southeast part of the town the meadow is at least a mile in diameter, and of an elliptical shape. In North Starksboro, near the source of the creek, there is a high terrace, No. 4, of great length. It is succeeded southerly by a wide meadow. A tributary of Lewis Creek, from the corner of Huntington, has accumulated some interesting terraces. The stream descends a valley crossing a mountain range, and at its debouchure has deposited a succession of latero-delta terraces, which project out into the plain. They are composed of sand, and from their height and projection are unusually conspicuous. Upon the south side of the stream at its debouchure, there are two terraces, Nos. 1 and 4. The south side of No. 4 supports two smaller terraces belonging to the same stream. On the north side there are five terraces. The highest terraces follow up this stream in the narrow valley, even to the summit level, between Lewis Creek and Huntington River. We have nowhere seen so curious a place for distinct terraces as at this height of land. Usually the valley is filled with moraine terraces at these watersheds; but here at the highest point there are two terraces, at least 50 feet high, one on each side of the valley, or meadow. More than this, they are continuous, or nearly so, with the highest terraces belonging to the streams on the two sides. Evidently there has been some stream of water across this valley, but what one we are at a loss to determine. The top of the terrace No. 5 in Hinesburg is 570 feet above Lake Champlain, and the top of the terrace at the summit level is 702 feet above the same level.—We could imagine that a stream crossed this valley and emptied into Lake Champlain, when its level was higher than at present, say to the height of the large terrace. We could comparatively easily account for its formation, but not so with the formation of the highest one. We will defer the discussion of this point till we speak of old river beds.

Laplop River rises in Hinesburg and empties into Lake Champlain at Shelburn Bay. It lies in the Champlain clays, and has cut a much deeper channel for itself in those deposits than any of the other streams already mentioned. The assignment of two terraces to this river on the map is eminently just.

TERRACES ON WINOOSKI RIVER AND ITS TRIBUTARIES.

Winooski River, called also Onion River, rises in Cabot, passes through Marshfield, Plainfield and Montpelier, whence it takes a northwesterly course, until it unites with Lake Champlain between Colchester and Burlington. It is 70 miles in length, and waters about 970 square miles. It has at least five basins of terraces upon its banks, which may be divided into several sub-basins, on account of the variety of circumstances under which they were formed. It is the first river we have met with, in our survey of the different rivers, that cuts directly across the Green Mountain range—and, excepting the La Moille and Missisco rivers, there is no other stream in the State thus situated. The nearest approach we found to be in Castleton river, which crossed the Taconic range in Ira. We should suppose that it would have been easier for the Winooski, La Moille and Missisco rivers to unite and flow to the south, forming a stream larger than the Connecticut, and parallel to it, east of the Green Mountains. Why they chose to cut through the high ranges instead, is entirely a matter of conjecture. But there is no doubt that the present routes were the best adapted to the wants of the inhabitants of the State, for had the course been otherwise—had the three rivers united and formed a grand rival to the Connecticut, the modes of communication between the east and west parts of the State would have been extremely difficult. It is much easier to pass down the easy grades of the Vermont Central Railroad, upon Winooski river, than to ascend mountains 2,000 or 3,000 feet high. And we cannot doubt that the course of rivers, as well as the deposition of beds of iron and coal, was designed for man's benefit, by the same Infinite Wisdom.

The first basin extends from the mouth of the river to Jonesville, containing three sub-basins. The first sub-basin extends from the lake to the gorge east of Winooski Falls village. It is particularly interesting, not merely for the scenery exhibited from some of its highest terraces in Burlington, but also from the union of two kinds of deposits—fluviatile and oceanic—or the terraces and Champlain clays. Upon the map it is seen that the land runs out to a point, just beyond the mouth of the Winooski. The extreme point is composed of Utica slate; then there is no rock seen until we reach a north and south line, connecting Mallett's Head and Lonerock Point, where a tough dolomitic limestone appears — the Winooski marble or limestone. The space between these two ledges is filled up with sand and loam, forming an extensive meadow, with a second terrace resting upon the ledge at the point, the northeast part, and in the south part parallel to the river. Probably these together constitute a delta, brought down to fill up the former vacant space between Colchester Point and the Winooski marble ridge. There are similar deltas at each mouth of the three large northern rivers. Upon Plate VII, Fig. 3, where the first sub-basin is represented, it will be seen that the first terrace is broad until we reach the railroad bridge of the Burlington Branch of the Vermont Central Railroad from Painesville. Then it grows narrow, and at the high bridge ceases entirely, its place being occupied by silicious limestone from which a deep gorge has been excavated. North of the river the third and fourth terraces are unusually large, each forming a plain several miles square. The highest is continuous from Richmond, gradually expanding from a point at Richmond to several miles in width in Essex. It extends nearly to the north line of Colchester, almost connecting with the highest terrace of the La Moille river. Its wide extent is represented on the general map, Plate II. On the south side, this fourth terrace is very extensive. Commencing quite wide on the Winooski marble ridge, it narrows and divides at Burlington, part running west, and the rest passing on east of the University. East of Burlington it expands again to a width of two or three miles, and narrows out gradually beyond Williston, becoming a point at Richmond. At Painesville this terrace is 240 feet above the lake. It is not very distinct in the village of Burlington, on account of the encroachments of man and of the lake upon it. The third terrace in Burlington is the flat just north of the common; the fourth between the common and the University, which is upon a hill of modified drift. We should not expect the terraces in Burlington to be well marked, because they are on the lee side, so to speak, of the terraces on the river. Whatever terrace-like forms appear ought perhaps to be considered as lake terraces, and belonging to Lake Champlain. Northeast of Winooski village, seven very distinct terraces may be seen rising above each other in succession, and extending two or three miles to the northwest. The highest of them corresponds in height with what has been called the fourth before. This great terrace, No. 4, we think may be regarded as a delta terrace, extending from Richmond to Lonerock Point. When the lake was at the level of its summit, this terrace must have occupied, besides its present situations, the whole of the valley now occupied by the Winooski below Richmond. So that, had the water dried up suddenly, there would have been presented to the eye a vast unbroken plain of sand from Lonerock Point to Richmond, and from Mallett's Bay, Colchester and Milton, on the north, to Williston village and South Burlington, on the south. Since that period, the Winooski has cut out its present channel and formed the lower terraces; and also tributary streams have done their part in excavating their own beds, and forming their terraces, while the level of the lake and of the channel of the Winooski were gradually sinking.

We stated that oceanic deposits were connected with these fluviatile accumulations. We shall hereafter state the particulars respecting these deposits (the Champlain clays), and will only anticipate a little.—Fifty feet below the plain of Burlington, and in the whole of the railroad excavation in the village, there may be seen strata of clay containing fossil marine shells, such as are now found living upon our coasts. The same may be found underneath the sand, over the whole of this high terrace. This shows us that it was probably the ocean in which this delta terrace was formed, and that the shells were mixed with the deposits brought down the Winooski. Hence this plain was formed by the joint action of the river and of the ocean; both the terraces and the clays are consequently of the same age. These shells have been found at a height of 300 feet above the lake, and therefore we may expect to find them in the valley of the Winooski as far as Waterbury. We have not examined the clay banks for them in this valley, for want of time. Should they not be found in future, we think the cause may be ascribed to the presence of a fresh water current.—Marine animals cannot generally live in fresh water. Perhaps this may explain the reason why we have not found these marine fossils in the valley of the Connecticut and other streams below the height of 500 feet above the ocean. On the Connecticut we can proceed to the Twenty-miles Rapids in Waterford, before we reach this altitude, but we know of no case between Waterford and Long Island Sound where these fossils have been found. So on the Hoosac and Battenkill Rivers.

Also the fact that sand only is found at this delta at the height of 240 to 260 feet above the lake, shows that the current besides being too fresh was also too strong for the deposition of clay or silt in which these shells are found. The character of the deposits on the Connecticut is generally sandy or gravelly, and where clay abounds it is possible that some of these were formed in basins separate from the sea, as they occur in the lowest portions of the valley, and are often filled with terrestrial fossils, such as wood, fruits and nuts. Upon this interesting sub-basin near Burlington, we will adjoin some remarks of the late Prof. Thompson, written for the Geological Survey in 1847, in a manuscript entitled *Geology of Chittenden County.*—They will illustrate positions already advanced by us respecting the extent of the highest terrace, and the distribution of the sands and clays.

"*Sands.* The deposits of sand of this period (older pleistocene) are quite extensive in Chittenden County, particularly in the towns of Milton, Colchester and Burlington. They are for the most part superficial, varying in depth from a few inches to 80 or 90 feet, and in general have a regular and nearly horizontal stratification. They usually terminate downward in brown or blue clay, and in many places the mixture of clay and sand is in the proper proportion for making bricks, as at the foot of Winooski Falls.—The elevation of the surface of these sand deposits varies from 20 to 260 feet above Lake Champlain. The mean elevation of those plains (terraces) to the westward of the range of [Winooski] limestone, extending from Lonerock Point to Mallett's Head, and thence to Milton, may be estimated at 40 feet; and the mean elevation of the extensive sandy plains commencing in Burlington, and extending through the southwestern part of Essex, and through the central parts of Colchester and Milton, is about 200 feet.—Marine shells are found in this sand in numerous places. At one place in Burlington, half a mile northeast from Lonerock Point, and by the side of the road, they abound in a coarse gravel about 130 feet above the lake; and two miles northeast of Mallett's Bay in Colchester, is a large deposit of them at an elevation of more than 200 feet above the lake. At both these places they are much broken, and mingled with rather coarse gravel. It would appear in these places, that the shells had been worked up above the line of the shore composed of drift, and that the gravel of the drift [terrace materials] was mingled with them by the action of the waves, and [these and larger objects like the fossil] whales were at length buried by the washing down of the drift materials."

We would also quote further remarks by Prof. Thompson, derived from the same manuscript. We will not alter any of the terms which he used, and will say, in respect to them, that the *drift* spoken of is obviously what has been designated in this Report as *Modified Drift*, and that the *pleistocene* deposits are the same things that we have denominated *Terraces*. The Principal of the Survey has thought best to simplify the numerous deposits of alluvium by denominating them *Drift* and *Modified Drift*, instead of the terms *Newer and Older Pleiocene* and *Pleistocene*, as used by Adams and Thompson. The former term applies to a tertiary deposit now found in the State.

"The term *drift*, when distinguished from the pleistocene sands and clays, is generally, I believe, understood to denote an older deposit, consisting of sand, clay, gravel, pebbles and bowlders, thrown together in great disorder, rarely exhibiting very distinct signs of regular stratification; and the appearance and situation of the drift in this county are for the most part conformable to this opinion. Still, however, there are some apparent exceptions. There are frequently deposits of what I should not hesitate to call pleistocene sand and clay, which are covered with deposits of what I should with equal confidence call drift materials. But these cases, if carefully examined, are not calculated to impair our confidence in the general opinion that the drift formation is older than the pleistocene. It will generally be obvious, that although materials of the drift period are lying upon the pleistocene deposit, they have been brought into that condition by the action of the waters of the pleistocene period. These are usually upon the side, or at the foot of a hill composed of drift materials, and it is easy to conceive that while this hill formed an island in that arm of the ocean which occupied the valley of Lake Champlain in the pleistocene period, the action of the waves upon the shores of this island might wash down the drift materials of which it was composed, and spread them out upon the stratified clay and sand previously deposited.

"This matter is well illustrated by the elevation upon which the village of Burlington is located; or rather some phenomena are here exhibited, which it is difficult to understand upon any other hypothesis. All the lower part of the village stands upon a deep deposit of pleistocene sand and clay, which is in general very regularly stratified. This deposit extends eastward, becoming gradually more elevated in departing from the lake. At the distance of a little more than half a mile from the lake, these sands begin to be mingled with, and in some cases to be overlaid by what I think are evidently drift materials. From thence to the summit of the elevation, upon which the University is located, the drift becomes more and more characteristic, and for some distance around the University the materials all evidently belong to the drift formation.

"The circumstances to which I alluded in the beginning of the last paragraph, and which give a deep interest to the geological formation upon which the higher parts of the village of Burlington are situated, are these:

"1st, It is asserted that living frogs have been here dug up at depths from five to eleven feet in the solid earth. 2d, That parts of trees and other vegetables have been here found imbedded in the solid earth at depths from ten to thirty feet below the surface.

"Accounts of cases under the first of these heads may be found in Williams' History of Vermont, page 479 of Vol. I. The author there states, as from his own observation, that as Moses Catlin, Esq. was digging a well about 20 rods south of the University, where J. D. Allen, Esq., now lives, the workmen, on the 12th of October, 1807, at the depth of about five feet, dug up *six frogs;* on the 13th *two*, and on the 14th *five*. These last were about eleven feet below the surface of the ground. At another well, 80 rods northeast from the University, he states also that a single frog was dug up on the 26th of October at the depth of eleven feet. The frogs in these cases were in a hard gravelly earth. When thrown out they were said to have exhibited their full powers of life and activity. Several persons are said to have been present when some of the frogs were dug up, and I have conversed with several persons who lived near the spots where they were said to have been dug up, and who, although they did not see them dug out, had no doubt with regard to statements which were made respecting them. Two of the frogs mentioned by Dr. Williams were preserved in alcohol in the University museum, where I frequently saw them when a member of the University, but they were destroyed when the building was burned in 1824. They belonged, if I may trust my recollection, to the species *Rana halecina*, the leopard frog, which is at present the common frog in our fields and meadows. In cases like those above mentioned, common observers, with the most honest intentions, are liable to be deceived, and it is hard for a naturalist to receive such statements with confidence, unless they have been subjected to a naturalist's scrutiny.

"2d. But whatever doubts may exist with regard to the exhumation of the living frogs, there is none, in my own mind, in relation to the remains of vegetables which are said to have been dug up in this vicinity. One of the most recent, as well as interesting cases of this kind, occurred in 1835. In that year the Hon. Alvan Foote, who resides at the head of Pearl Street, and about 40 rods directly north of the University, dug a well near his house, of which he furnished me the following particulars:

"The natural surface of the ground in the neighborhood of where the well was dug had numerous large bowlders scattered over it, and was originally covered with a heavy growth of timber. In digging, the first three or four feet below the soil he found loose gravel.—He then came to what is commonly called hard pan, which was composed of pebbles, gravel, sand and clay very solidly compacted together. This reached downward about 20 feet, and it was necessary to loosen it with a pickax in order to carry on the excavation. At the depth of about 24 feet below the surface of the ground the earth became less solid and could be shoveled without being previously loosened with the pickax. After penetrating this sand about four feet, on forcing the shovel into it, all at once it went down, apparently into a vacant cavity, almost the whole length of the handle, to the no small terror of the man who was using it. Upon examination, it was found that it had entered a cavity occupied for the most part by the remains of a tree which must have been about two feet in diameter. It was nearly horizontal, extending in an eastern and western direction. The greater part of the wood which remained was rotten and quite soft, and yet some considerable portions of it were perfectly sound, as was also the bark generally. Some of the sound portions of the tree were taken out and whittled with a knife, and Judge Foote pronounced it, without hesitation, to be white pine. Unfortunately none of it was preserved. The distance from the natural surface of the ground to the tree was carefully measured, and found to be 29½ feet.

"The whole body of the tree was enveloped in sand, which was six or eight inches deep directly beneath it. At this depth the workman came to a stratum, several inches thick, of muck, or swamp mud, which afforded evidence of having been formed of decayed sticks and leaves.

"That the foregoing is a correct statement of facts there can be no reasonable doubt.

"Here, then, was a tree buried 30 feet deep in the solid earth, and the question is how it came there. To answer this question, a careful consideration of the circumstances will be necessary. Now the surface of the ground where this well was dug is about 250 feet above Lake Champlain. The site of the University is 277 feet above the lake, and the highest part of the elevation, upon the western declivity on which the village of Burlington is built, is about fifty feet higher or about 327 feet above the lake. The surface of the country around this well is much lower in all directions than the place where the well was dug. It is plain, therefore, that the tree could not have been buried by materials brought down by any river.

"Was it then covered during the drift period? The materials certainly resemble the deposits denominated drift; but as we find no organic remains in our drift, unless this is an exception, I am disposed to refer it to what we have called the pleistocene period. Now we have abundant evidence that after the formation of the immense deposits of the drift period, there was a general subsidence of the whole valley of Lake Champlain to such an extent that all places, which are not now as much as about 300 feet above the lake, were submerged beneath the waters of the ocean. When, in the course of this subsidence, the surface of the ground where the buried tree lay was depressed to the level of the arm of the ocean,—then occupying the valley of Lake Champlain—the summit upon which the University stands must have been an island composed of drift materials, and elevated about 100 feet above the surface of the water. At this period the island must have presented towards the north a steep bank, composed of loose materials, at least 60 feet high, at the bottom of which, nearly on the level of the water, was a small tract of swampy ground. Now as the subsidence went on and the water flowed in upon the swamp to the foot of this bank, the waves, acting upon the finer portions, would wash them down, cover up the muck and also the tree which had lodged on the shore at the foot of the bank. The first part of the process, on account of the steepness of the bank

and the looseness of the sand, might have been so rapid as to cover the tree before it had time to decay. Afterwards as the ground continued to subside, additional materials would be continually washed down and spread out towards the north; and during an additional subsidence and re-elevation of about 50 feet, there is no difficulty in conceiving that a sufficient quantity might have been deposited over the tree, and have been so compacted together as to exhibit all the phenomena described by Judge Foote. Indeed I think we have here abundant evidence in several places that drift materials have been mingled with, and in some cases spread over the pleistocene sands and clays, by the actions of the waves of the sea which occupied this valley in the pleistocene period.

"In the case of the frogs* mentioned by Dr. Williams, if we admit that the observers were not deceived with regard to their exhumation, the places and circumstances were precisely such as would lead us to conclude that they were buried precisely in the same way we have supposed the tree to have been."

In his *Appendix to Natural History of Vermont*, Prof. Thompson describes two more cases of fossil wood. "In making the excavation on Pearl Street, for the reservoir, connected with the aqueduct, which supplies the lower part of Burlington with water, at the depth of 13 feet from the surface of the ground, a large amount of wood, sticks and leaves were found imbedded in clean gravel. The locality is about 200 feet above the lake, and the size of the excavation was 36 feet by 40. The surface of the ground sloped moderately towards the northwest, and was originally covered with timber. The earth, after getting below the soil, was sand and gravel, which had been washed and assorted by water, and was lying in irregular beds, sloping steeply towards the northwest. The vegetable remains formed a mass in the gravel about two feet wide, one and a half feet deep, and 36 feet long, extending in a right line, and was at first mistaken for a rotten tree; but on breaking it to pieces, it was found to consist of roots, limbs, bark, stems and leaves snugly bedded together, and all of a dark brown color, some portions of it approaching, in appearance, to brown coal. Many of the sticks and roots were perfectly sound, and exhibited the structure of the wood completely, and are, I have little doubt, the American Larch, *Pinus pendula*.

"In October, in laying the aqueduct pipes in the south part of the village, wood, resembling larch and oak, were found at the depth of 10 feet below the hard pan, and in April, 1852, in deepening the well at the Pearl Street House, which is midway between the two localities first mentioned, a piece of wood, ten inches long, six wide and three thick, was found below hard pan, 24 feet from the surface. The Pearl Street House is about 230 feet above the lake. Wood has also been found in the central part of the village, in the stratified sand and clay, 20 feet below the surface."

*The opinion of the Survey respecting these frogs, may be learned by an extract from *Hitchcock's Geology, thirty-first edition*, 1860, *page* 234. "Many well authenticated instances are on record, in which toads, snakes and lizards, have been found alive in the solid parts of living trees, and in solid rocks, as well as in gravel, deep beneath the surface. But in these instances the animals undoubtedly crept into such places while young, and after being grown could not get out. Being very tenacious of life, and probably obtaining some nourishment occasionally by seizing upon insects that might crawl into their nidus, they might sometimes continue alive even many years."

From experiments upon this subject it has been found that if toads are buried deep in the ground, when cut off from all supplies of food, and with only a limited supply of air, their lives are sometimes prolonged as much as two years. These conditions are not as favorable, by any means, as the cases described by Prof. Thompson.

We add an interesting account of a relic of civilization, discovered in this modified drift in Burlington, in a letter from A. D. Hager to the *Burlington Times*:

Burlington, Aug. 17, 1859.

D. W. C. CLARKE, ESQ.:

Dear General,—The Burlington Aqueduct Co., in excavating for a well in William Street in this place, at the depth of nine feet, and 235 feet above Lake Champlain, encountered a bed of carbonaceous matter, closely resembling Lignite or Brown Coal, about four feet thick, from which there arose a strong odor, closely resembling that from a coal pit.

In opening a ditch north of the well, to conduct water to the reservoir on Pearl street, the same lignite bed was reached, and found to extend north 72 feet, varying in thickness from two to five feet, and gradually dipping to the northwest, till it disappeared beneath the ditch. About 18 inches above the north end of this bed there was found another bed of lignite, 45 feet in length, and evidently occupying what was a basin-shaped depression in the surface at the time of its deposit. This upper bed varied from two to fourteen inches in thickness — the greatest thickness being near the center of the bed. In both of these beds, which rest upon quicksand, there were found fragments of limbs, roots and bark of exogenous trees, in a remarkable state of preservation, and also "fruit" or seeds. It is a remarkable fact that many of the bits of wood found in this deposit show the unmistakable marks of the beaver, or some other *rodent*, at the ends where they are cut off. Several varieties of seeds were found, among which are those resembling seeds of the grape, tomato, cabbage, &c., &c.

Mr. John D. Pickering, a gentleman whose veracity is unquestionable, being requested by a lady to procure for her some of the "seeds" found in the Lignite, took a solid lump which the workmen had just dug out, and thrown up to him, and with his knife commenced picking it in pieces for the seeds, when he struck the point of his knife upon a hard substance resembling the green carbonate of copper. The substance he carefully dug out, and, upon removing the external coating, found it to be a piece of copper about the size of a cent, and about as thick as a five cent piece.

It was very much corroded, but perfect enough on one side to disclose very plainly near the center the figure "6," and beneath it near the edge was engraved '1709.'

The lignite from which this was obtained was taken from near the center of the upper bed, and was 7½ feet below the surface. Above this lignite bed there are continuous and very regular strata of sand and gravel, evidently deposited by water. There is not the least evidence that the strata have ever been disturbed; and from Horace Loomis, Esq., a gentleman who has lived in Burlington since 1790, and from Phineas Lyman, Esq., who has resided here since 1795, both of whom reside near, and are familiar with the land, I am assured that no excavations have been made at that place, nor has gravel ever been placed there by human agency. But the outline of the surface is the same, or very similar, to what it was when covered with a heavy growth of timber, which was not more than seventy-five or eighty years ago.

In several other instances fossil wood has been found in making excavations in Burlington, notices of which are given in the Appendix to "Thompson's Vermont," pp. 55 and 56.

Frederick Smith, Esq., the gentleman who superintended the construction of the reservoir on Pearl street, informs me that at the depth of 13 feet he encountered a tree which he estimates was about forty inches in diameter, and extended quite across the excavation, 40 feet square.

Mr. Pickering has kindly presented the ancient copper *coin* (?)* to me, to be placed in the State collection at Montpelier, where it will be exhibited with the fossil wood, seeds, &c., found in connection with it.

Respectfully yours,

ALBERT D. HAGER.

Returning to the terraces in the first basin on the Winooski River, we will notice those about the gorge near Winooski village. No terraces can exist where these rocks are found, but the rocks did not constitute a barrier high enough to separate the terraces into two basins, because the highest terrace is higher than the rocks; and if our view of its formation be correct, it once covered these rocks. But we have thought the division into sub-basins very appropriate, because this rock is a complete barrier between the lower terraces west and east of it. The gorge itself is described in another part of the Report.

The highest terraces in the second sub-basin from Penniman's limekiln to Richmond have already been described. East of Penniman's limekiln the meadow expands, and is of a triangular shape owing to a bend in the river. Several terraces are found upon the south side of this triangle. Near Painesville there are found Nos. 1, 2, 3, 4 and 6, the latter being insulated on No. 4 near the railroad junction. The rest of the basin nearly to Richmond, west town line, has no terraces except the meadow which is composed of clay, and No. 4, already described, composed in its upper part of sand. It is along this beautiful valley that the Vt. Central Railroad runs, and it is a very advantageous route for a railroad.

At Richmond, near the west line of the town, is the limit of the second sub-basin, for here we find ledges of rock showing themselves, and intercepting the terraces upon the north side.

The third sub-basin extends from Richmond to Jonesville, the limit of the first basin.

At Richmond, just west of the village, there is a curious enlargement of the meadow nearly into the shape of a semicircle. It extends north of the river for more than a mile. It is upon a small stream, too insignificant to receive a name upon the county map; it being only two miles long. East of the meadow there is a tongue of terraces, extending nearly to Winooski River, upon the second of which is located the village of Richmond. Five large terraces, mostly of sand, compose this tongue. Still farther east the meadow expands to the north like the semicircular plain west of Richmond, but is of less width; and this expansion is situated west of a tributary stream, without name, which is about four miles long. The arrangement is represented upon Plate V, Fig. 3. A third expansion of the meadow, still smaller, is seen at Jonesville. Besides the meadow, there are two small terraces on the north side. On the south side of the Winooski the terraces are compressed laterally, and the fourth terrace is the most common. In Jonesville at the mouth of Huntington River, there are four terraces in succession on the tongue of land between the Huntington and Winooski Rivers.

At Jonesville we arrive at ledges of talcose schist which are beautifully striated, and have formed a decided barrier to the first basin. The embossed rocks have taken to themselves the whole valley. From Jonesville to Waterbury, the terraces are generally narrow, though often quite high. This region is an excavation across the back bone of the Green Mountains. Hence as the exertions of the currents have been mostly devoted to wearing away the solid rock, we should not expect to find many terraces, although the excavation was principally made before the drift period. At intervals in this cut there are some very high terraces. We noticed respecting some of them, that at certain points where a ledge projected towards the river, thereby narrowing the valley, the highest terraces and greatest accumulations were found. Some of them must have been 200 feet high. Two cases were noticed in particular, at two extensive excavations

* The figures were not raised, but coarsely engraved in the copper, and this evidently was never milled like common coin.

in the talcose schist through which the railroad passes. Between these and other projecting points, an oval shaped meadow was seen, like the expansion in the first basin. We suppose that these high terraces are gorge terraces, for like them they were deposited near obstructions. The current, which was transporting materials along the wider part of the valley, when it impinged against the projecting ledge would momentarily have its velocity diminished sufficiently to allow the detritus to descend below its influence. It is in this way that gorge terraces are formed, when they are found at the upper side of gorges. But here there was nothing which could be called a gorge — simply an obstruction. The ledge may not have reached the surface of the water: it was not necessary that it should have done so to sustain our suggestion.

When looking at some of these cases in 1857 in ascending the valley for the first time, with our eyes open to the beautiful striation and embossment of the rocks, we surmised without much thought that these gorge terraces were invariably upon the lee side of the embossed rocks, and that therefore they might have been *moraines*, i. e. resulting from the remarkable drift current that ascended the valleys so much like a reversed glacier. In the following year we descended the valley, and saw that these accumulations were made up of fine materials, and that in some cases they were found upon striated rocks as well as on the lee side. Hence we adopted the former explanation for their formation, at the same time allowing that their materials were mostly derived from the latter source.

We regard the district from Jonesville to the Falls in the west part of Waterbury as forming a distinct basin, although the terraces are not numerous, nor the eastern limit well marked. In it there are at least three projections of ledges on both sides of the river, corresponding to ridges of the Green Mountains,— as the fine County Map of Mr. Walling shows,— and there are four oval meadows between the ridges, in each of which may be found two small streams, one from the north and the other from the south side of the Winooski. Hence we see that these small streams assisted in the formation of the meadows. We might indeed call these expansions sub-basins, for they are as truly sub-basins as those enumerated in the first general basin.

Emerging from the Green Mountains we enter the third basin, which at Waterbury street expands very much to the north and south, as represented on Plate VI, Fig. 2. On the south side, there are four large terraces, not remarkably distinct, succeeded by moraine terraces, all of which run up the valley south of Duxbury Center, the first large valley east of Camel's Hump. On the north side is Waterbury street, which is situated upon the first and second terraces. The second, third and fourth terraces make quite a curve north of the village, skirting the Winooski at the west end of the curve, at the mouth of Thatcher's branch. Winooski River formerly ran around the village at the foot of this curve. Beautiful and large terraces follow up the Winooski east of Waterbury for a mile or two, then dwindle down and are lost in the west part of Middlesex, being intercepted by a rocky barrier, the remnant of a former extensive chain of hills. Five terraces were occasionally seen upon the south side of the Winooski, on this basin, in Moretown.

The fourth basin extends from West Middlesex to Montpelier, at the point where the Winooski makes a bend, running to the northwest for half a mile, the hill west being mostly naked rock. West of Middlesex, on the north side of the river are five large terraces, across which may be traced some old river beds. As they are found opposite the mouth of Mad River, and are of limited extent east and west, it is safe to infer that the materials were brought down Mad River, and arranged by the Winooski, not being transported down the Winooski, on account of the barrier. At Middlesex there is a deep gorge and falls in the Winooski River. East of the village on the north side, a high terrace may be traced to West Montpelier to the Cemetery. And in this district also, on the north side, may be seen at least three expansions of the meadow,— one in particular, nearly two miles from the State House, being quite noticeable. On the south side the terraces are more limited, there being scarcely any in the east part, and only two in the west part, near Middlesex.

In the village of Montpelier, no terrace apart from the meadow or first terrace, upon which the town is built is seen, except in the east part behind the houses, where every one has noticed the side of a flat hill, which exhibits marks of stratification very distinctly. It is composed of clay, is considerably wide across

the top, and is marked as No. 4 upon the Map. The first terrace is composed of clay east of Montpelier.— Besides this terrace in passing to East Montpelier, we find generally one, though there are often two others, which are ranked as the third and fourth. Many of these terraces are composed of clay. Between this village and Marshfield the terraces are very similar, not being numerous, but often quite large. They may be seen upon the general map, with such variations as occur in their number, extent and situation.— We have regarded this basin as extending to the Great Falls in Marshfield, although it cannot be considered as well marked. Beyond the Falls there may be another basin extending on both branches to the ponds in Cabot, from which the Winooski takes its rise.

Returning to glance at the tributaries of the Winooski, in ascending from Burlington we first strike Muddy Brook in the east part of that town. The work accomplished by this small stream has been mainly to cut through the highest terrace of Winooski River, and thereby produce two terraces. This brook is small and quite short.

The most interesting of the tributaries is Huntington River, which rises in Huntington in the long triangular part of the town, and joins the Winooski at Jonesville, in E. Richmond. The first two miles of the stream, reckoning from its mouth, have only two terraces upon their banks. The river descends rapidly here, and in one place passes through a gorge. Then the river becomes more crooked and makes a great bend in the south part of Richmond. A high terrace on both sides of this bend continues to Huntington; and the terraces below the highest are well developed. This part of the valley forms a distinct basin of terraces, which are represented upon Plate V, Fig. 3. These terraces are found upon the small tributaries also and extend to the south part of the town. So gradual is the ascent, that we do not consider the terraces to belong to more than one basin. But it should be especially noticed, that these terraces are very well marked, more so than usual. Their special variations are noticeable upon the general map.

Upon a previous page we have noticed a remarkable terrace in the southeast corner of Huntington, on the summit level between Lewis Creek and Huntington River. The same terrace descends the tributary to Huntington, and is continuous with the highest terrace on Huntington River to Richmond. We have noticed another similar case on the hill road from Huntington to Jonesville. At the highest point in the road there is a most distinct valley, with a terrace 20 feet high on both sides of it. The valley, or first terrace is 624 feet above Lake Champlain; the second terrace is 641 feet above the same level, which is 105 feet higher than Huntington, and 61 feet lower than the high terrace in S.E. Huntington. Hence the bottoms of these two elevated valleys cannot be far from the same level. We did not take the height of the meadow in the first case, and can therefore judge of its height only from the highest terrace. We regarded that as 50 feet high, in the former case, and it is 17 feet by measurement in the latter case.— This would make the difference in height between the lowest points in the two valleys to be only 28 feet.

We had supposed the latter case (on the town line of Huntington and Richmond) to have been the valley of Huntington River at a former period, it being only 100 feet above the present level of that river. In that case there must have been a very great wearing away of rock subsequently. If so, on account of the nearness of height of these two summit levels, we may suppose that these high terraces in both cases were formed by Huntington River, upon a former continent.

Upon a stream coming down from the east side of Camel's Hump in Duxbury there are a couple of rough terraces at its mouth.

Waterbury River and Thatcher Branch have terraces upon them; in the latter case, they are numerous and distinct, running up to Waterbury Center.

At the mouth of Mad River in Moretown there are no terraces, because the river is forced through a narrow passage in the rock. Higher up there are three upon each bank, and we have reason to suppose that they are more numerous still in Moretown village.

Three and four terraces were seen on Kingsbury branch, occasionally, between Montpelier and West Montpelier. The railroad passes up Dog River between the west part of Montpelier and Northfield.— Occasionally terraces were seen upon its banks, and between Northfield and Roxbury there may be seen a very high terrace composed of coarse materials. A few terraces occur on Molly's Brook in Marshfield.

TERRACES ON LA MOILLE RIVER AND ITS TRIBUTARIES.

La Moille River is not as large as the Winooski, nor quite as long. It rises in Greensboro, from the union of several streams (formerly from Runaway Pond), runs southwest to Hardwick, when it turns northwesterly, passes through the middle of La Moille County, the south part of Franklin County, and finally joins Lake Champlain in the northwest corner of Chittenden County, in the town of Milton. Its current above Cambridge is in general slow and gentle, but below Cambridge it is interrupted by falls, and is more rocky. There are five basins of terraces upon it. And in general we may say, respecting the terraces on this river, that they are larger and higher than upon any other river in the State.

The delta of the La Moille River is quite interesting. It is not so extensive as that of the Winooski, but its general features are the same, so far as the delta is completed. On the Winooski, we stated that the whole country west of the Winooski limestone range had been brought there by the Winooski River, and that the delta had reached a ledge of Utica slate, formerly an island. We find the same conditions at the mouth of the La Moille, but the process is not yet completed. The river has cut through the Winooski limestone range, which is much higher in Milton than in Colchester, and has deposited a delta of one or two miles in extent beyond it, mostly made up of very low land, it being the first terrace. There are, however, three terraces at its eastern border. This delta is triangular in shape; and upon the County Map there may be seen an arm of the lake from the north side of the *sand bar*, approaching almost to the La Moille, about a mile from the lake. There can be no doubt that the river formerly entered the lake by this channel, in addition to the present one, and that the famous sand bar between Milton and South Hero was formed by their joint action. This bar is nearly one and a half miles long; its width we have no means of ascertaining, as the bottom of Lake Champlain has never been surveyed. Formerly this bar was fordable at low water, but now there is a bridge, or road built upon it, by forming an embankment of the common decomposing (Utica) slate rock of South Hero. When this road was constructed, it was thought that as the river entered the lake below the bridge, its detritus, when brought down into the lake, would be washed by the waves upon the road, and thus protect the embankment from the action of the water. This principle is doubtless correct, but it is a question of time. Already there has been quite a large quantity of sand accumulated at the east end for several rods; but the prevalent winds from the south have dashed up waves against the embankment, so that it has been badly injured in the middle and west parts. As the slate decomposes easily, disintegration has gone on more rapidly during the ten years since it was erected, than the proprietors have desired. It is now in a poor condition, and we see no better way in which it is to be repaired, than by bringing upon it more pieces of rock, perhaps of a harder kind than the slate.— Fortunately there is a ledge of tough limestone near by, than which no better article could be procured.— The hill just east of the flat in Milton, is entirely composed of this rock, and if fragments of it could be placed upon this embankment to fill up the holes, and form a macadamized road, great benefits would ensue. A road would be secured, not easily worn away, and the ridge thus formed would gradually collect the sand about it, until the delta of the La Moille shall have reached South Hero; in other words, have reached the island of slate rock, which its sister stream at Colchester Point has already done.

At this bridge-road the sand has accumulated on the north side, although there is no stream of any account below to transport it. We account for its transportation in this way: the former mouth of the La Moille, in conjunction with the present, formed the sand bar, and consequently at the north the bar is quite wide. We believe that for some distance north of the road the water is very shallow. If so, the waves would naturally wash up sand from the shallow bottom against the embankment, and as the sand is heavier than the water it would be left there, forming a beach, just as the ocean forms beaches at the present day. We know of no other way in which it could have collected, unless in the times of freshets and high storms, the water should flow over the road from the south to the north, and then carry over the sand. We think, however, that this is not often the case — we were not informed in regard to it, learning only from our informant that the water on the south side was frequently two or three feet higher than upon the north side. We adjoin a few words from Prof. Thompson's manuscript, relating to this bar, and to the filling up of Lake Champlain with detritus:

"No observations have been made to determine the manner in which the materials washed from the shores, or conveyed by the streams, are disposed of by the lake. But that the lake is constantly but slowly filling up and its depth diminishing, there can be no doubt. It is not probable, however, that these materials are distributed over its bottom with any degree of uniformity. In some places they are undoubtedly thrown into ridges by the action of the waves, forming banks or bars. The *sand bar* joining Milton to South Hero, was probably formed in this way. There are strong reasons to believe that the La Moille River, which now empties on the south, formerly emptied to the north of this bar. This river, which traverses a large extent of sandy plain, must formerly have brought into the lake a vast amount of sand. This sand, being checked in its flow towards the south, and thrown back by the south wind which prevails here, is thought to have been the means by which this sand bar has been formed. When the lake is low, this sand bar renders it fordable between Milton and South Hero."

By looking at the map any one will see that if the La Moille formerly entered the lake by the north channel exclusively, it never could have formed this bar, because the current would be directed towards North Hero instead of South Hero. Hence we have suggested that it probably flowed through both channels like the Missisco River, which now passes through several channels to the lake. Moreover there is an island now forming at the present mouth of the La Moille, which by steady growth will make as large an island between future channels of the river, as the former island between the ancient channels. It will also be seen how unnecessary it is to suppose that the work went on formerly and not at present, as Prof. Thompson's language seems to imply. We have supposed that the work is now going on, and the deposit of sand at the east end of the road, and at other places on the lake, proves it.

The other point to which we wished to call attention in this quotation, is the steady increase of the land below the level of the lake. No one can doubt that the lake is filling up, and it is precisely in this way that terraces are now forming. A large amount of detritus is brought into the lake from time to time. It gradually rises to the surface of the water, and can by no efforts of the river rise more than two or three feet above the surface of the lake, or to the maximum rise of the waters. Now we contend that the whole of the sandy point has been thus formed, and if the lake should now within six months sink fifty feet, these sand banks and bars would project as level-topped terraces, wherever they had reached the top of the water before it sunk. Then if the water should remain stationary for another long period, and then sink, or if it should sink gradually, another set of terraces would show themselves along its borders. It is precisely in this way that the great plain or terrace east of Burlington, and extending through Colchester and Milton into Georgia, was formed. When the lake was 260 feet higher than it is now, it covered this plain, which had been steadily accumulating for hundreds of years. When the continent rose, the water was drained off, this plain was left dry, the rivers cut their present channels through it, and as the drainage was gradual, lower terraces were formed (seven in one place) as well as the deltas of the Winooski and La Moille rivers, which are still increasing in size.

The first basin on La Moille River extends from Lake Champlain to Georgia railroad station. Possibly the barrier of red Winooski limestone may have kept the lower limit of the basin at a short distance from the lake for a time. The greater size of this ridge, that has been worn through, may be the reason why the La Moille has a smaller delta than the Winooski and Missisco Rivers. We see not why this position is not tenable.

We can say but little respecting this basin. We have seen one or two points only within it. At Milton Falls we noticed at least five trim terraces on the south side of the river, and three or four on the north side below the level of the fourth terrace or the great plain. This terrace upon the south side extends to the north part of Colchester, and is about three miles wide. We cannot give the limits of this terrace upon the north side with definiteness. Georgia plains constitute a part of it, and its western limit is generally the range of Winooski limestone near the lake shore. Cobble Hill is almost surrounded by this terrace. At the depot on the Vermont and Canada railroad in Georgia, the eastern limit of this terrace and basin is reached.

We took two observations with the Aneroid Barometer upon this highest terrace at intervals of three miles, and found its altitude in both places exactly the same—132 feet above the La Moille east of Georgia depot, or 321 feet above Lake Champlain. The river makes a bend at E. Georgia, and in the sub-basin thus formed, we noticed two and four terraces upon the north side, and four beautiful ones on the south side. Passing east of the railroad bridge we found no terraces whatever for a mile or two. In their place the surface gradually sloped from the tops of the hills on either side to the river, the slope being composed of scanty water-worn materials except where ledges showed themselves.

Soon we pass the barrier, and in Fairfax are ushered into the second basin. West of the village of Fairfax the highest terrace (perhaps a beach) is very large. The map (Plate V, Fig. 4) shows us at the west end of the basin three terraces upon the north, and four upon the south side. They soon give place to the first and fourth on both sides, each of which is unusually large. We think that the fourth terrace in Westford, on the south side, along Brown's River, extends to the Winooski River, and that an old bed of the river is found along the same course. The surface is sandy, though probably underlaid by clay. The highest and lowest terraces extend uninterruptedly to Cambridge. At Fairfax Falls we should consider the basin limited did not the highest terraces continue on uninterruptedly; for the river falls here 40 feet over talcose schist. At Cambridge Borough there is a narrow passage for the river, and though the highest terrace continues upon the south side, we regard this ledge as the boundary between two basins. This is the west end of the cut through the Green Mountains, and in this respect the village of Cambridge on the La Moille corresponds to Jonesville on the Winooski River. But the valley of the La Moille above these villages is much the wider of the two, and its terraces are scarcely less extensive than they are at Fairfax and Fletcher. Just within the third basin, among the mountains, and near the backbone of the range — the continuation of Mansfield Mountain — there are five large terraces on the north side offset against Nos. 1 and 4 on the south side. Near the east line of Cambridge Nos. 1 and 5 occur upon the north side, and four successive terraces appear on the south side. Those that succeed in Johnson, are represented upon Plate V, Fig. 5. Just west of the village of Johnson, another barrier is seen corresponding with the one in West Waterbury on the Winooski River, and the fourth basin opens before us, holding the village of Johnson in its lap. The valley expands very much, and there are five terraces on both sides; the highest of which on the north side is 190 feet above the La Moille at Johnson. East of the village we find the valley blocked up with great terraces. The highest one is in the middle of the valley, and though now isolated, was doubtless formerly connected with the sides of the valley. It is marked as No. 6 upon the map, and is 277 feet above the river, and 737 feet above the ocean. It is composed of sand and gravel. Four terraces occur upon the east side of this gigantic pile, and appear like steps artificially prepared for a giant's staircase.

The highest and lowest terraces accompany one another east of Johnson into Hydepark, with occasional additions to their number, often four in succession. They gradually expand, till at the Hydepark Court House, and in Morristown, the extent of the two highest terraces, Nos. 3 and 4, exceeds the limits of any high terraces noticed upon any river in Vermont heretofore, away from their mouths. Hydepark is in the center of a great valley running north and south between two great ranges of mountains, and the detritus from both sides seems to have centered here. The terraces are probably four miles wide upon the La Moille, and we were unable to follow up the valleys to ascertain the extent of terraces upon the tributary streams. We think the amount of terrace materials accumulated in Hydepark and Morristown upon the La Moille, greater than at any other place in the State, unless we were deceived by the open and wide valley and the appearance of the distant terraces, for we were obliged to hasten through the town without careful examination. In the east part of the town, the terraces have again contracted to their customary width, though still of great thickness. Our notes show five terraces on each side of the river in the west part of Wolcott.

At Wolcott Center the terraces are perhaps higher than usual, because since they were formed the river has cut through the rocks some fifty feet, as evinced by pot-holes. From Wolcott we went up to Eagle ledge, passing up the valley of a small stream. Along its course we found terraces, and when above the terraces at a height of 600 to 700 feet above Wolcott, fine sea beaches were observed.

Between Wolcott and Hardwick the highest terraces are enormous. We measured one that is 380 feet above the river, and 1100 feet above the ocean. This is the highest terrace that has been measured in Vermont, and higher than any that we have seen recorded in North America. The highest terrace elsewhere in the United States, whose height we have seen recorded, is at Genesee, N. Y., which is 348 feet above Genesee river. It should be kept in mind that this may not be the highest above the ocean, but the highest above the river at its base.

In Hardwick the high terraces continue till the stream has become much smaller. At South Hardwick there are four terraces on each side of the stream, which are intercepted by a ridge of calciferous mica schist; which may be considered as the limit of this basin. For one or two miles below, ledges have shown themselves occasionally in the valley.

In the fifth basin, extending from South Hardwick to Greensboro, on the main stream, there are some very fine terraces. The first and fourth only are seen upon it, except at one place on the northwest side of the stream in the north part of the town, where four terraces may be seen rising above one another in succession. In Greensboro there is a large beach which supplies the place of the terraces.

We have been able to follow up only one of the tributaries of the La Moille river. That was in Elmore, and it has already been stated that terraces were found upon it. These terraces are often quite large. We could not follow up the course of the stream in the valley, because there was no road in it, although there is a proposal now made to construct a road from Wolcott to Montpelier along this branch.

A. D. Hager traveled upon one of the branches of La Moille river, between East Hardwick and South Hardwick, and made the following observations: "One fourth of a mile below East Hardwick a terrace extends for the distance of half a mile, whose base is clay. On the opposite side are numerous moraine terraces of gravel. One mile west of East Hardwick three terraces appear on the north bank, ten, fifteen, and thirty feet high severally, and extend for one half a mile in length. Two and one fourth miles, at a bend in the river, there is a terrace or moraine one hundred feet high. Near this place in the river is an enormous bowlder of the concretionary granite from Craftsbury. There is clay at the bottom of a terrace in South Hardwick."

TERRACES UPON THE MISSISCO RIVER.

The Missisco River (sometimes written Missisquoi) rises in Lowell, east of the principal range of the Green Mountains, flows north into Canada, where it has cut through the range, returns to Vermont in Richford, and after pursuing a southwesterly course through Franklin county, at Swanton Falls finally turns to the northwest, and enters Lake Champlain through six channels, in Highgate. Its length is 75 miles.

The delta at the mouth of the Missisco river is larger than that of the La Moille and Winooski rivers, and its character as a delta will more readily be admitted. The land projects into the lake at the mouth of the Missisco, including Hog Island — which would hardly be suspected to be an island — and two irregular tracts. The whole of this projection we regard as the delta, for it is all low land, mostly composed of sand and other alluvial products. And besides the six present channels of egress for the river, there were once two others, which are called Charcoal Creek and Dead Creek. Instead of the ridge of Winooski limestone, which we found to exist at the mouths of the Winooski and La Moille rivers, there is a small ridge of slate and limestone, running from Highgate Springs to Swanton Falls, lying east of the delta. The lake, however, is filling up here as in the former places, and there will doubtless be a union at some future time of this delta with Alburg, leaving room only for the passage of the river.

East of the delta we have represented the terraces in Highgate, and about Swanton Falls, so far as they have been observed. At the Falls there are two terraces on both sides of the river. Going north about a mile, on the east side of the river, we see another terrace, very regular in its proportions, and extending north for three miles towards Highgate Springs. In the north part of its course, it is quite narrow. East of it, and stretching out to a great distance, is No. 3. Following down the river from Swanton Falls for some distance, upon the north side, the terrace designated as No. 2 appears, and is situated on the bank like one of the great levees common on the Mississippi river. And in fact it is a levee in this instance.

The terraces are fine all the way to Highgate Falls, and their distribution may be learnt from Plate II. At the Falls there are four terraces upon the south side, and only the third and fourth upon the north side. The valley between the highest terraces is quite narrow between Swanton Falls and Highgate Falls.

We can say but little respecting the Modified Drift of Missisco River above Highgate Falls, because when we traveled along its upper part in 1857, we took no notes of the phenomena. We are quite sure, however, that there is no remarkable development of terraces upon it. At Sheldon, we crossed the stream in two places without seeing any terrace accumulations worthy of mention. At East Berkshire, and along the river to Richford, there are occasionally expansions in the valley lined with terraces, as at the villages of East Berkshire, and of Richford. Above these villages in Canada, and in the towns of Troy and Lowell, the bed of the valley is rocky, and though filled with some of the most beautiful examples of drift striæ to be found in the State, terraces are scarcely developed.

RIVER TERRACES IN ORLEANS COUNTY.

We have not explored Orleans County, because it was assigned to another assistant, the Rev. S. R. Hall, of Brownington, who took very few notes in reference to terraces. One or two flying visits have enabled us to state the character of the valleys upon a few of the streams.

The Black River of Orleans County is thirty miles long, rising in Craftsbury and discharging its waters into Lake Memphremagog. We crossed it at the village of South Coventry, and found that besides the meadow and frequently several small terraces, a very large and high terrace extended on both sides of the river at the village, and north and south as far as the eye could reach. We understand that similar terraces extend over most of this river. It is a sluggish river, and its meandering outline on the map suggests an alluvial country lined with terraces. This high terrace at South Coventry extends to Lake Memphremagog and unites there with a lake terrace. The same one passes up Barton River, on both sides of the stream, probably as far as Barton; beyond which they gradually become less perfect to its source in Long (Runaway) Pond, in Glover. This part of the state is remarkably prolific in surface deposits. The terraces are not noticeable for their number so much as for their great size and extent. We regret that when we passed up an immense terrace on the east side of Barton River, on the road to Brownington from Coventry, that we did not ascertain its height, for it seemed as if we had never seen a higher one. Terraces are found on Willoughby River, which connects Lakes Willoughby and Memphremagog. A deep valley connects these two bodies of water, and the highest terrace on Memphremagog Lake is 200 feet lower than the level of Willoughby Lake.

We did not notice any interesting terraces upon Clyde River in Charlestown. A large valley belonged to it, but it was made up of low land underlaid by beds of peat and marl. Perhaps it is the bed of an old pond.

II. LAKE TERRACES.

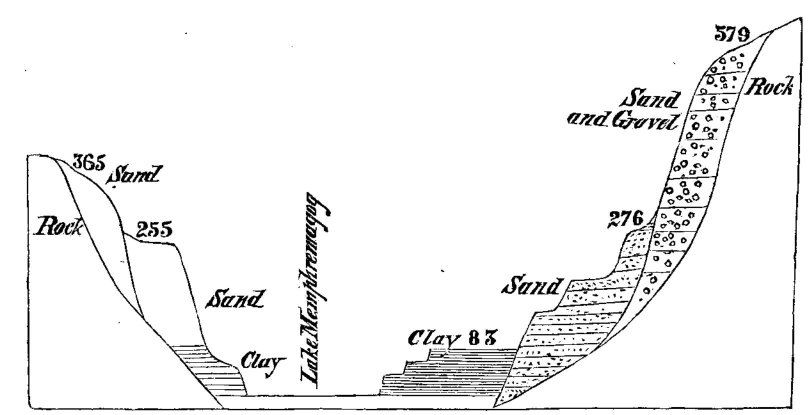
We have now finished our detail of facts respecting river terraces. Although many of the streams have not been visited or carefully explored, sufficient has been said to give much information upon this neglected subject. A Geological Report should mention all the facts respecting its appropriate phenomena which can be obtained, whether they coincide with theories or not. And when these facts, seemingly unimportant, from the different parts of the State, and from other States, shall have been brought together, some master mind will reduce them to order, and assign proper theories for their explanation. At the present age, scientific men are too apt to speculate in the absence of facts: hence the array of facts upon any subject or department of Geology, cannot be too great. We want to know the facts just as they are, even though a Report cannot be filled with new discoveries. If we cannot sketch remarkable cases of dislocated rocks, or disturbed strata, let us give views of common, plain phenomena; and though they may not impress by their singularity, they will make their mark upon science by their inherent truth.

We do not propose yet to account for the origin of Lake Terraces, in distinction from River Terraces.—We have already given suitable definitions, and will proceed to describe these terraces as we find them in nature. And as we were just describing phenomena of River Terraces in Orleans County, in the vicinity of Lake Memphremagog, we will commence with this lake in our description; especially as this lake affords the best examples of Lake Terraces of any lake or pond in Vermont.

Memphremagog Lake is thirty miles long, two or three miles wide, and is 685 feet above the ocean.—It lies mostly in Canada, only seven or eight miles of the south end extending into Vermont. About 15 miles of territory are covered by its waters in Vermont. We have examined only the south end, having extended our researches to Owl's Head Tavern, two or three miles into Canada. Over this space the terraces are found only at the south part. A large mountain on the west side, and a great mass of granite on the east side, have no terraces upon their flanks. But we doubt not that terraces are numerous at the north end of the lake, and we presume that "Stanstead Plain," has been formed by the lake. We give a section of the terraces at the head of navigation. The altitudes were taken by the Aneroid Barometer.

The section in Fig 64 is partly ideal, as the high beach on the east side is a mile or two south of the line of the section. The two highest terraces are found on both sides of the lake and pass up its two tributaries, Black River and Barton River. A church and village (West Derby) are located upon the third terrace on the east side. The highest one on the east side extends several miles back into Derby, and as the height corresponds with that of the central village of Derby, we presume the plain extending from this terrace east is the same with the plain extending north from Derby into Canada; and that though the lake could not deposit any terrace materials near its borders on the mountains, it left its materials east of the granite hill. The materials of the different terraces are represented in the Figure. The three lowest are of clay, the others of fine sand, which is sometimes so abundant as to injure the crops. All the materials in the basin of Lake Memphremagog are unusually fine.

Fig. 64.



Section across the valley of Lake Memphremagog.

We would have been glad of an opportunity to visit the country east of this lake in Orleans and Essex Counties. From Mr. Hall's Report we understand that the country near the north line of the State is undulating, the soil good, and the surface not very rocky. We shall anticipate the discovery of many interesting phenomena illustrating Surface Geology. The numerous ponds and lakes would probably exhibit many interesting terraces and ramparts.

A small pond in the edge of Salem, lying partly in Brownington, has a few terraces upon it. At its west end a small stream empties into it, and at its mouth there are some terraces; two upon the north side of the mouth of the stream, and three upon the south side. We should estimate the highest one to be 75 feet above the level of the pond.

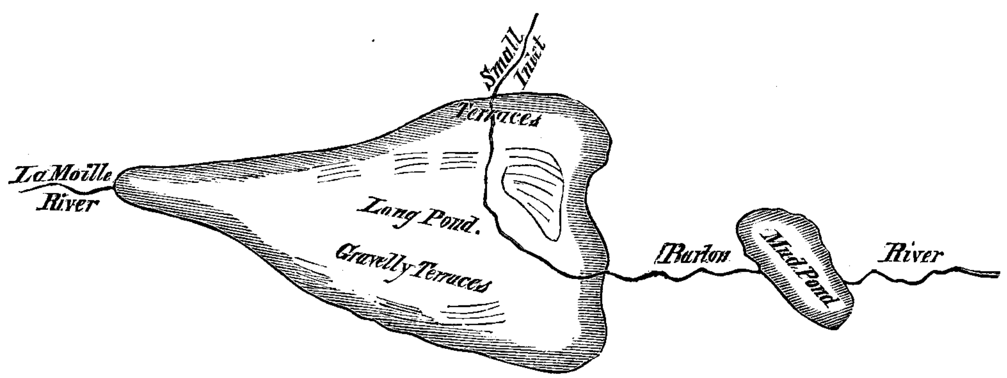
Willoughby Lake is not situated where terraces can well be produced. It lies between two high precipitous mountains of granite, its south end is blocked up by moraine terraces, and there is an outlet proceeding from the north end. As it is very deep, probably terraces are now forming underneath its surface.

In the northeast part of the state there are many other ponds and lakes, upon which there are probably many terraces. We have, however, been unable to examine them.

At North Montpelier there is a pond of small size, less than a mile in length, upon which we saw three very distinct terraces. The idea was suggested to us when seeing it that possibly these terraces were formed by the sudden departure of its waters, like the Runaway Pond in Glover. The pond is properly an expansion of a stream, but its terraces are much more perfect than those in the stream above or below.

The terraces formed by the Runaway Pond in Glover are properly lake terraces, having been formed by the pond, and brought to view as terraces by the bursting of the barrier 40 years ago. We give a figure* (Fig. 65), to represent the former and present condition of Long Pond (as it was called) and Mud Pond.

Fig. 65.



Long Pond was one and a half miles long, and about half a mile wide, situated partly in Glover and partly in Greensboro. At the south end the water was shoal for about five hundred yards, not being over ten or twelve feet deep. It was also shallow at the edge of the whole pond, but in the middle and over the greater part of the pond more than 100 feet deep. It was situated upon the height of land between the valley of La Moille River on the south, and of Barton River and Lake Memphremagog on the north. The descent on the south was extremely gradual. Out of a channel of a yard's width flowed a dull streamlet, through trees, shrubs and rocks to the south, the only way of egress. A small inlet flowed in from the west side.—Upon the north side was a shore some five or six feet higher than the surface of the pond, forming a narrow belt to restrain the waters within their former limits. About 200 rods north of Long Pond was Mud Pond, about 200 feet lower than the former. Originally there was no communication between them, and Mud Pond was the source of Barton River. It was three-fourths of a mile in length, and half a mile in breadth. Its bottom was a mass of deep mud, of a rusty dark blue color. The bottom of Long Pond was covered with an indurated calcareous clay, called *hard pan*, and varied in thickness from two to eight inches. Upon this was marl and black mud, which when wet would run like water, and when dry was very light, and of a blue color. This hard pan reached out from the shore into the pond, resting upon a quicksand at the north end, and was the only thing that had prevented the bursting of the barrier long before.

At the time of the inundation, the country on Barton River was mostly a wilderness. Barton River descended rapidly for five miles from Mud Pond over a rough bed of sand and pebbles, and then more gradually with a margin of meadow on either side to Barton. At Keene Corner, four miles from Mud Pond were two mills, a saw mill and a grist mill, owned by Mr. Wilson. Three miles below Barton was a grist mill owned by Mr. Blodget, and three miles farther were the mills of Mr Enos. - Besides these, there were a few dwelling houses upon the route of the inundation. A full account of this inundation is given by Rev. S. R. Hall, in another part of this Report.

In Williamstown, near the height of land, and within a mile and a half of the *Gulf Spring* are three lake terraces, formed like the terraces on Long Pond by the bursting of the barrier, though the material accumulated was not as great on account of the smaller size of the pond. It is called Lime Pond, on account of the vast amount of marl accumulated there, and used for the manufacture of quicklime. We visited the locality in 1857, and obtained various facts from Mr. Samuel Hibbard respecting the history of the rent, and the value and use of the marl.

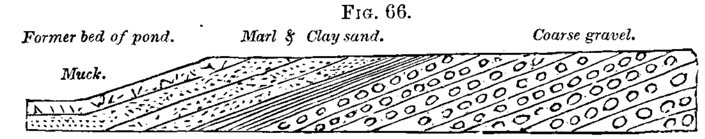
* The figure and facts of the description were furnished by Rev. S. R. Hall.

This pond was 941 feet above the ocean, was partially crescent shaped, was computed to cover eight acres, and was from 20 to 25 feet deep. It was situated like Long Pond in Glover, at the height of land. Below it on the east side, was a saw mill, fed by a stream that was not quite sufficient to carry the wheels at all seasons. By similar arguments that urged the inhabitants of Keene Corner to their work in Glover, Mr. Josiah White the owner of this mill in Williamstown was incited to open a trench in the barrier of the pond, about thirty years ago, to increase his mill privilege. Similar results followed the opening of the trench. The water rushed out through an opened passage about twelve feet wide, and increased the stream more than was desired, for a short time carrying along great stones and tearing up trees in its course. The mill was saved with difficulty. Because the outlet was small, the water of the pond did not all rush out in a dense column ; and thereby its effects were not so pernicious upon the property in its path.

The bed of the pond that remains is quite interesting. It is entirely composed of marl of the best quality, which is burnt for quicklime, and sold by the owner, Jason Fuller, at a profit. A large part of the marl is located in a terrace which was around the pond below the former water level, and is about ten or twelve feet high. Near the outlet of the pond, where the pond was the deepest, and the water ran for the longest time when the barrier burst, there is another terrace about three feet high. These two, with the meadow (calling the meadow the first terrace), make three lake terraces, formed by the draining of a pond. It is an interesting case, because it shows us that the drainage of ponds forms terraces precisely like those lining the beautiful basins of river terraces that we have been describing. To be sure these terraces are very small, but they illustrate a great principle, and are an epitome of the manner in which terraces have been formed upon all our rivers. It is not uncommon to find beautiful exhibitions of diminutive basins of terraces in those ephemeral ponds formed by heavy storms. We have often examined their dried beds, and found the whole phenomena of terraces exhibited upon them in miniature. There will be lateral and delta terraces where a larger stream than usual flowed into this pool—we have counted seven or eight in some cases—and again there will be the terraces surrounding the pool formed by the numerous washings in of sand around the edges of the pond, which forms at the successive levels of the water. We have fancied sometimes even that a more interesting section might be derived from these minute examples than from the large basins in nature, because when observed immediately after their formation, they are more perfect than their analogues on some large stream.

The former limit of Lime Pond may be seen most distinctly by the *water mark*. Around almost every pond at the water's edge, there are numerous bushes, which often form a dense tangle. There was such a shrubby wall surrounding Lime Pond in the days of its glory ; and now that its glory is departed, this line of shrubs remains, indicating the former level of the water more exactly than any measurements that man could have devised would have done, at the lapse of thirty years after the removal of the water. This water line is made more distinct by the contrast between these clumps of bushes around the pond, and the fine growth of grass that occupies the former bed of the pond. The excavation through the barrier of the pond has left an interesting gorge, of which we have given a section in Fig. 66. The gorge is about ten rods long and fifteen feet deep. The outer part about six rods in length on the surface, is composed of coarse gravel and drift materials, which are, however, stratified, and consolidated in some places, being as tough as conglomerate. Next to the conglomerate is a bed of fine sand about six feet thick. This is a quicksand, and was the cause of the break. Next we see calcareous clay mixed with marl, containing an abundance of shells, and occasionally vegetable matter. This is quite thick, extending over nearly three rods of surface, and dipping at an angle of 20° to the west, or under the water (formerly.) Succeeding the marl and clay is a deposit of peat over a foot in thickness, which is in the bottom of the pond, and is now forming in the swampy portion. A great portion of the meadow is very swampy.

Fig. 66.



Section in alluvium at Lime Pond, Williamstown.

We think of only one other example of lake terraces that has passed under our notice ; and that is near Tyson's Furnace, in Plymouth. There is a pond here, which is properly an expansion of Black

River, upon the banks of which, upon the east side in particular, we noticed two or three quite distinct terraces. This is in a region of very fine scenery, to which these terraces add by their interest and beauty.

We are hardly prepared to point out any distinct terraces upon Lake Champlain. As the lake partakes so much of the character of an inland sea, we should hardly expect to find distinct terraces, but rather beaches. Yet some of the largest lakes in the country have terraces upon their borders, as Lake Superior, where there are sometimes fifteen, according to Prof. Agassiz. We may perhaps regard the great delta terraces of the Winooski, Lamoille and Missisco Rivers as terraces of Lake Champlain, for they were evidently formed under the waters of that lake. We refer more particularly to the high plains upon these rivers, already described as existing in Essex, Colchester, Milton, Georgia and Highgate. They were formed by these rivers and by the lake at the same time. Neither agency was sufficient without the other, and they may properly be classed either as lake or river delta terraces. To the same category belongs the great terrace in S.E. Hinesburg, 570 feet above the lake, upon a tributary of Lewis Creek.

Apart from these accumulations brought down by rivers, there are terrace-like accumulations south of Burlington, which in the field we mapped as terraces of Lake Champlain. But we did not venture to place them upon our final map, because they are so connected with the Champlain clays that we could not separate the two; and besides, the lower silurian rocks near the lake form hills, so frequently like terraces, that it is possible that the plain and its corresponding slope which we had marked as terraces, are in reality bluffs of Trenton limestone, etc., covered with clay. We would, however, refer to a few of these cases. In Charlotte, east of McNeil s landing there is quite a wide plain, and there is a higher level tract above it in the village of Charlotte. In fact, from North Charlotte to Ferrisburg there are four different levels, which curve with the hills of red sandrock. There are only three at Vergennes, the city being upon the third of them. To the south, the ridge running from Panton north of the Elgin Spring, through Addison, Bridport and Shoreham, might almost be called the fourth terrace. West of this ridge is a depression, which near the lake rises into two distinct levels in West Panton and West Addison. East of Bridport village there are six different levels. In the southern part of Shoreham, and in the towns between Shoreham and Whitehall, the surface is so studded with small rocky hills, that no regularity of surface can be traced. We cannot regard these plains as terraces,—they are perhaps beaches,—but we mention them here because of their resemblance to lake terraces. The material of which these elevations are composed, above the rocks, is mostly clay. It was formed under water, and the formation will be described under *Champlain Clays*. Of *maratime terraces* we have already spoken, describing them as formed by the waves of the sea shore, but distinct from sea beaches. We have as yet found nothing in Vermont to be referred to this class

IV. MORAINE TERRACES.

A class of terraces formed when water covered a great part of Vermont, were described as moraine terraces. They were said to be a peculiar form, not unfrequently assumed by the more elevated terraces, exhibiting great irregularity of surface; elevations of gravel and sand, with correspondent depressions of most singular and scarcely describable forms. The name is not so characteristic as it should be; but no better name has been suggested. It was given under the impression that stranded ice as well as water was concerned in their production.

These phenomena have gone under the name of "dry bowls" in the northern part of the State. Others call them "tracts of drift beds, covered with sink holes," "a field of mounds or moraines *inverted*." Prof. Adams called them moraines—an improper term, because moraines are formed only by glaciers, and several real moraines have been already described in this report, from different parts of the State.

We will simply give a catalogue of all those cases of moraine terraces which we have noticed in the State, and subsequently state our theory respecting their origin:

In Pownal they are abundant in the east part of the town, in the valley of the principal branch of the Waloomsac river.

Between Shaftsbury and Arlington they are met with frequently. At Arlington, west of the village, are conical and tortuous moraine terraces above the terraces on the Battenkill river.

Some of the most interesting examples of moraine terraces occur in the valley between the Green Mountains and the Taconic range. In the northwest corner of Sunderland they may be seen upon both sides of the valley. They are very extensive in the north part of Manchester, upon both sides of the valley also, being almost continuous from Sunderland. "One of the most remarkable is half a mile southwest of the east village of Manchester. Although it is composed of extremely loose materials, it is so steep as to be ascended with much difficulty on the south side, where it is 150 feet high. On the north side, less regular masses of the same structure cover a large area." C. B. ADAMS.

Extraordinary accumulations of moraine terraces occur in the valley between East Dorset and Danby. They are situated upon the watershed of the Battenkill river and Otter Creek, in a remarkably deep valley. It is remarkable that the largest accumulations of modified drift to be found are so often located similarly in other parts of Vermont, as well as New England.

Following down Otter Creek, moraine terraces may be seen extending through the greater part of Danby, and at North Wallingford. They are continuous from this village to the village of Clarendon. In the narrow valley on the west side of Mt. Eolus, the vast amount of moraine terraces is surprising. They are on the road from Danby Corners to West Dorset. At the north opening of this valley upon the mountain range west, one may observe irregular mounds and depressions very much resembling moraine terraces. They are not composed of loose materials, however, but are simply hillocks of limestone, which have been fashioned by streams of water.

In the northwest part of Tinmouth, passing into Clarendon, may be seen other examples of moraine terraces.

They are particularly abundant in the east part of Rutland, near the line of Mendon, most of the length of the town, lying at the foot of the great range of quartz rock.

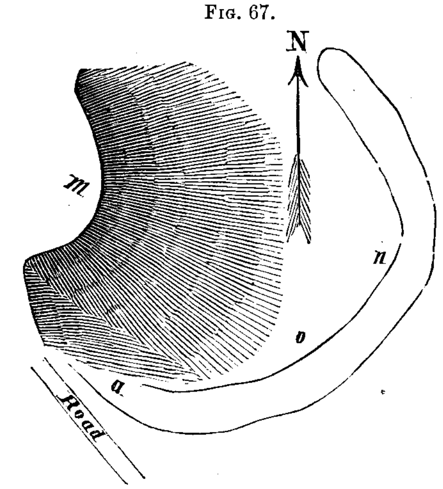
At South Chittenden, also at the extreme south corner of the town.

Between Pittsford Furnace and North Chittenden, upon the northwest side of Furnace River, is one of the finest examples of moraine terraces in the State. Good sketches of them might be taken at several points.

In the valley of Sugar Hollow River, a branch of Furnace River, about two miles north of the village of Pittsford.

In the east part of Stratton there are moraine terraces. Also in the valley in which the village of Windham is located. Very fine ones in East Londonderry and a little west of North Londonderry, the latter 1487 feet above the ocean. It is a fine region in Windham, Londonderry, Landgrove, Peru and the adjoining towns, for all drift phenomena.

Fig. 67.



At Peru there is an interesting curved moraine. We give Prof. Adams' figure (Fig. 67.) "A remarkable example occurs in the east part of Peru, a few rods north of the Peru turnpike. In the accompanying figure, *m* is the east side of a north and south range, which at *m* is about 150 feet above its base *n*, but rises higher to the west; *a* is the southwest extremity of the moraine [terrace], which here joins the hills without any intervening depression, leading off on a level in the direction *a c*, and at *c* approaching near to the base of the hill. The top varies but little from a level; the total length is 1000 feet; the width of the base is about six rods, and of the top from three to six yards. It consists of a yellowish brown gravel with some small bowlders. The road is represented upon the southwest side."

Moraine terraces are found also upon the south side of Mt. Ascutney, in Weathersfield; they are represented upon a section of terraces in Fig. 56, where they are from 160 to 613 feet above the Connecticut at Weathersfield north line.

Near Proctorsville (north), upon a small stream emptying into Black River, near Gov. Fletcher's house.

At Proctorsville, a pile of modified drift blocking up the mouth of the Gulf—the gorge in which the carriage road from Proctorsville to Chester is located.

In the north-west part of Norwich, at an elevation of 712 feet above Connecticut River at White River Junction.

Near the Strafford Copperas Works, 172 feet higher than the preceding locality.

At Thetford Centre.

Near Williamstown Center there are numerous mounds of water-worn materials, referable, most probably to these phenomena. The whole country in this vicinity bears the marks of water action. The barrier of Lime Pond is part of a moraine terrace. All these are near the summit along the route of the Rutland and Burlington railroad, near Cuttingsville, and in the towns of Mt. Holly, Wallingford, Shrewsbury and Clarendon. They are very large in this region.

At Rutland, east of the village; and between Rutland and Rutland Center, running north. Also upon the south side of Otter Creek at Rutland Center. At the cut through at the Taconic range in the north part of Ira, the passage way of Castleton River, and of the Rutland and Washington railroad. At Ripton, east of the village they are very numerous and extend up the Green Mts. to an old sea beach near the top of the mountain. They are 1070 feet above the ocean.

In the south part of Leicester, and extending south, into Brandon. At Johnson, south-east of the village; represented on Plate V, Fig. 5. Upon the height of land between La Moille River and Black River, on the boundary line between Hardwick and Craftsbury, 803 feet above the ocean, on the route of an old course of La Moille River to Memphremagog Lake, along the present valley of Black River. On the line between Wheelock and Greensboro, these deposits are quite large. At Hydepark, in that great valley east of the Green Mountain Range, are the "dry bowls," which are probably moraine terraces.

In a Report to Prof. Adams in 1846, Mr. Hall says of these phenomena:—"In the easterly part of Hydepark, the *drift* is very common, and many *basins* were found, some 50 to 70 feet deep; in which water never accumulates, so as to prevent the growth of timber in the bottom, or so as to form swamps or wet land. These basins are of all shapes and sizes."

Also at the south end of Willoughby Lake in Westmore. There may be a barrier to prevent the waters in this lake from flowing to the south, like the former barrier of Long Pond in Glover, on the road to Memphremagog from South Troy, about five miles from South Troy.

We add the following, discovered since writing the above. In the west part of Jamaica. West of the village of Bondville, in the east part of Winhall. Through the greater part of the town of Plymouth, upon Black River.

Near the bend of Otta Quechee River in Sherburne there are curious accumulations of moraine terraces, which have been noticed in the description of the terraces upon Otta Quechee River.

In Poultney upon an old river bed, three miles north of the village.

At Underhill Flat the moraine terraces are abundant, and beautifully rounded, upon both sides of Brown's River.

Between East Hardwick and South Hardwick.

V. ANCIENT SEA BEACHES.

We have already mentioned many of these banks of sand and gravel when treating of the terraces. We propose now to give a full list of such beds of water-worn materials as we are inclined to refer to oceanic shore action for their origin.

At Marlboro, in the east part of the town. This is upon the valley of Whetstone Brook, near its source. The amount of water-worn materials was not large, and it is not so well marked a case as we should desire. It is 1113 feet above Connecticut River, and 1327 feet above the ocean.

In Rockingham, between Saxton's River Village and Cambridgeport, upon the north side of the river, there is some resemblance to a beach upon the hills above the terraces. We were unable to examine it carefully.

In Rockingham Center, on Williams' River, there is a very distinct beach at the village upon the south side of the river, it appears in the form of large rounded hills, which continue westward in the form of a bank upon the side of the hill. Upon the north side of the river, it extends back in the shape of an arc of a circle, as if it were the shore of a small bay. Its height is estimated to be from 600 to 700 feet above the ocean.

On the west side of the Green Mountains, there are more decided cases of old beaches. At Shaftsbury Center there is one quite distinct, which is 643 feet above the ocean. It may extend to Arlington upon a ridge in the center of the valley, much like a terrace. At Shaftsbury depot the lithological character of the small sorted pebbles is so very marked, that not even the most inveterate opposer of our theory of their formation could doubt that they were water-worn. We have not seen a finer example of a modern beach on any part of the shores of Lake Champlain.

On the map we have marked a beach from Cuttingsville to Rutland on the east side of the railroad, amid which are some moraine terraces.

Perhaps there is a beach commencing near the village of Pittsford, and continuing north to Forestdale in Brandon; being found along the west slope of the Green Mountains, and above the Champlain clays, fringing their borders. We should estimate its height at different places from 600 to 800 feet above the ocean.

A still finer example may be found in the east part of Ripton, lying partly in Hancock, near Flint's tavern upon the top of the Green Mountains. This beach is composed of stratified sand and gravel, and has the proper form of a beach, approaching a terrace. It overlooks the whole valley west of the mountains, and is 1806 feet above Middlebury, 1696 feet above the Champlain clays, and 2196 feet above the ocean. It is the highest beach that we have measured in Vermont.

In the northwest part of Norwich there are two beaches at the heights of 1287 and 1337 feet above the ocean. They are upon the same hill not more than half a mile apart.

In Strafford at the Copperas Works there is another beach. It is situated upon the hill back of the Copperas Works, 150 feet above them, and is 1340 feet above the ocean. It has a distinct terrace form, and is 22 feet below the top of the hill; the space above the beach being rocky, the cliffs against which the waters may have dashed in former times, and worn off materials for this beach beneath.

We are inclined to regard the deposits on Thetford hill as an ancient beach. The village is 878 feet above the ocean.

There is a beach on the east side of Connecticut River in the northwest part of Lyme, N. H.

In the southwest part of Newbury on the road to East Corinth, near the height of land, we measured an ancient breach that was 1488 feet above the ocean. Another, half a mile west of this one, was 1239 feet above the same level. On the east side of the Connecticut, in Haverhill, N. H., there appeared to be quite an extensive beach, as we saw the surface of the country from Mt. Pulaski.

Passing up the Connecticut, in Ryegate, Barnet and Waterford, there are accumulations of water-worn materials which have been referred to sea beaches. We are not sure but that a re-examination of them would lead us to refer them now to old Sea Bottoms.

East of Connecticut River in New Hampshire are the highest beaches that have been measured in this country. At Franconia Notch there are beaches at the heights of 2449 and 2665 feet above the ocean, and at the White Mountain Notch at the height of *1569 feet above the ocean. These were measured by the Principal of the Survey.

In Victory (west part) the materials are water-worn at a height of 1738 feet above the ocean, and may be regarded as forming an old beach.

In North Hardwick and Greensboro there was an old beach, the top of which is 1240 feet above the ocean. Others of about the same height may be seen upon the south side of the La Moille River in Elmore and Woodbury.

In the west part of Fairfax, on the La Moille River, above the terraces, are accumulations referable to a former shore, either of Lake Champlain or the ocean, at least 350 feet above the lake.

In the valley of Lake Memphremagog we have measured two or three beaches. One on the western side of the lake in Newport is 365 feet above Memphremagog, or 1060 feet above the ocean. One or two

* Said to have been measured by Prof. A. Guyot. It is at the same elevation as the White Mountain House.

beaches may be reckoned on the east side of the valley in Salem and Brownington, at the heights of 276 and 579 feet above the lake, or 971 and 1274 feet above the ocean. We have no doubt that others might be found in this part of the State; nor are we sure but that some of the "highest terraces" may come under this head. Craftsbury Common 1158 feet above the ocean, we have not seen, but from its representation we should judge it to be an interesting terrace or beach.

Upon the hill east of Sudbury Post Office there are two beautiful sea beaches, closely resembling terraces. They are about an eighth of a mile long. The upper one is about twenty-five feet higher than the lower one, and (approximately) is 570 feet above the ocean. It is probable that marine shells may be found in them, as they are so near the level of the Champlain clays.

Between Milton Falls and Colchester, there is a beach upon the east side of the Vermont and Canada Railroad, quite high up the side of the valley.

Commencing at the village of Starksboro, and extending north for a mile upon the east side of the valley, there is a very clear case of an ancient sea beach. The small water-worn pebbles are exceedingly numerous. Two miles south of the village of Starksboro, there is a beach, probably at the same level as the previous one. Both are nearly 1000 feet above the ocean.

VI. ANCIENT SEA BOTTOMS.

If we find evidence of the existence of shores of ancient seas, we should expect to discover the remains of their bottoms; and it seems to us that in Vermont, as well as in other parts of New England, especially in the more elevated portions, the many gravelly and sandy plains and low ridges can be explained only by the former presence of the ocean above them, with its waves, tides and currents. In the vicinity of Connecticut River they are less obvious, because in the lower parts of the valley, drainage has, in a measure, obliterated the marks of oceanic action, and the materials have been converted into terraces. The sides of the valley also rise too rapidly to expect many such accumulations of detritus as form sea bottoms. In the neighborhood of the present bed of the ocean in other parts of the country, and in those parts of Vermont that are nearest the ocean, by their small elevation above it, we find the surface covered with such materials, and in such forms as the ocean must have produced. In Massachusetts, Connecticut, and Rhode Island, we see this statement exemplified in the comparatively low region, within twenty, or thirty miles of the coast. In Vermont it is shown in those extensive deposits of clay in the Champlain valley, which are not generally found above 500 feet above the present ocean level. The proof in the latter case is made much more satisfactory by the great abundance of fossil marine shells, strewed over the valley.

In those parts of the State where Sea Beaches, Sea Bottoms, Moraine Terraces and Terraces are found, the same valley may sometimes contain all these phenomena. If the ocean has stood at several successive levels, as our researches have led us to suppose, what may have been the bottom of the ocean when it stood at its greatest altitude, may have become the level of the shore at a subsequent period, and still later, the place where Moraine Terraces and Terraces have been formed. Hence we should expect to find the oldest and highest forms the least perfect, as is the case.

We will describe the localities of these Ancient Sea Bottoms, mentioning first the oldest and highest. If the ocean once covered the tops of Jay Peak and Mansfield mountain, as is shown by the striæ upon them, surely the whole of Vermont might justly be called the bottom of a former ocean. Yet it would collect detritus only in certain places, and it is

such collections that we would notice. Properly speaking, the *drift*, also, was accumulated below the surface of the ocean. But we draw a line of distinction between Sea Bottoms and Drift; the drift accumulations were collected together by the joint action of water and ice; the oceanic deposits were the finer materials of the drift sorted out and transported, or else are drift, modified subsequently by aqueous agency.

In addition to the moraine terraces in the east part of Pownal, there are beds of gravel and sand, which we should refer to Old Sea Bottoms. They are not confined to East Pownal, but may be found along the valley of the Hoosac River, in Pownal Center, and continuing along to Bennington. Another example is in the west part of Bennington. The wide valley north of Mt. Anthony, extending to Shaftsbury, including the three villages of Bennington, has many alluvial deposits upon it that can be referred to no other agency for their formation. And in fact there are beds at intervals along the whole of this great valley, from Connecticut, through Berkshire county in Massachusetts, to Addison county in Vermont, which are to be ascribed to this same agency. We find the shores of this ocean upon the summits of the Green and Hoosac Mountains, and why should not the bottom of that ocean be found in the valley below?

In the south part of Brandon is another noticeable deposit of this description.

In the town of Washington, in Orange county, the alluvium is so extensive that we found it difficult to learn the dip of the older rocks, as they were all out of sight. This deposit is water-worn, and should be referred to the class of which we are now treating, at least to the height of sixteen hundred feet above the present level of the ocean. As the adjoining towns, particularly Williamstown, are covered with similar deposits, the same name should be given to them, at least as low as seven hundred feet above the ocean. We did not mark any sea beach upon the map for the higher grounds of Washington, but are inclined to believe that the highest parts of this deposit might properly be referred to beaches.

One of the most noticeable and interesting features that remained indelibly impressed upon us, when standing at sunrise upon the summit of Mansfield Mountain, and admiring the grand view spread out beneath, was the existence of several great north and south valleys running through the State. Foremost was the great Champlain valley, at its commencement in Danby exceedingly contracted, but gradually widening through Rutland, Addison, Chittenden and Franklin Counties, till it was lost in the greater valley of the St. Lawrence. East of us there was a wide valley, from Jay and Troy in Vermont, extending much farther in Canada, and passing through Stowe and Waterbury. East of this was the great valley of Lake Memphremagog. Upon this subject we find a few remarks from Mr. Hall, which we will quote:

"There are several valleys that seem to have a remarkable continuity in direction, nearly opposite to those through which the present leading rivers flow, in which are often found the remains of ancient river deposits, regularly stratified; and in many places, of as great depth as river deposits found in the present valley of the Connecticut, Merrimack, and other large streams. One of these extends from Lake Memphremagog, through Coventry, Irasburg, east part of Albany, Craftsbury, Hardwick, Woodbury, East Montpelier, Barre, Williamstown, Brookfield, Randolph and Bethel to White River, and perhaps farther. There is at Williamstown an elevation of a few hundred feet, (907 above the ocean) and another at Woodbury (about 1500 feet above the ocean.) Otherwise there is very little difference in the general level through the whole of this chain of valleys, from the level of the places where the La Moille, Winooski and White Rivers intersect it.

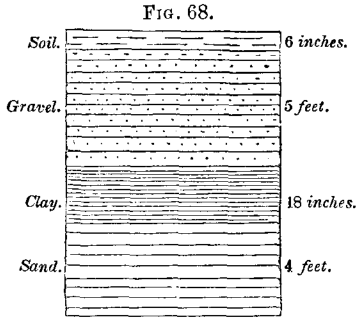
"The Valley through which the Barton river now flows, in which 'Dry Pond' (Long Pond) is situated, and which is occupied by the head waters of the Lamoille above Hardwick, continues through Walden and Cabot to Joe's and Molly's Ponds, and I suppose may be traced from thence to 'Onion River Pond,' and 'Wells River Pond,' and perhaps farther. The valley through which the Missisco flows, before entering Canada is readily traced from Troy to Waterbury."

We should extend this valley farther, viz.: up Mad River through Moretown, Waitsfield and Warren, to the sources of the west branch of White River in Granville, thence down this stream through Hancock, Stockbridge, and perhaps farther, so as to connect with the valley of Deerfield River. We doubt not that these and other interesting valleys would be brought out by a regular Topographical Survey of the State.

It is in these great valleys that we find numerous deposits referable to Old Sea Bottoms, a few of which we will specify.

All the geologists who have had charge of this survey, have remarked the extent of the deposits along the Missisco valley in Jay and Troy. Prof. Adams says of them, "We rode eight miles [from Lowell] to SouthTroy to breakfast. Most of the way was along an immense pleistocene fluviatile deposit, resembling those of Black and Barton Rivers; that is, with the remains left by subsequent denuding agency seldom existing in the form of regular terraces, as in most of our valleys, but cut into irregular elevations and depressions." Dr. Hitchcock in 1857 remarked, when traveling over this same region, "that it was an old sea bottom." The same deposits are found between South Troy and Lake Memphremagog, a distance of seven miles. The structure of this deposit, we learn from Mr. Hall, is similar to that of a terrace at Westminster,—ascertained from a well upon the farm of Esquire Sumner, in South Troy,—at first a thick bed of gravel, then three feet of blue clay, and at the lowest depth, quicksand.

Fig. 68.



Section in Alluvium at Bethel.

Dr. Hitchcock noticed the materials near Hazen's Notch to be growing coarser and coarser in traveling from north to south, thus indicating a current towards the north.

Mr. Hall has given a section of the materials upon one of these great valleys in Bethel. It is in the north part of the town on the gulf road, and is represented in Fig. 68. The first layer is clayey soil, the second five feet of coarse gravel, the third is eighteen inches of clay, and sand extends to an unknown depth.

We regard most of the northeast part of the State in Essex and Orleans counties, as an old sea bottom. Its water-worn character is decisive, and, so far as we have seen, it is more like a deep water than a shore deposit. This is many miles square.

CHAMPLAIN CLAYS.

The great valley west of the Green Mountains has more extensive sea bottoms within it, than any of the depressions east of the same range. Its deposits have two or three characters distinguishing them from those in the others: 1st, they are mostly composed of clay; 2d, they contain numerous remains of marine shells, etc.; 3d, the strata containing shells have not as yet, in the Champlain valley, been found higher than 400 feet above the present sea level. Their former character, as marine deposits, is doubted by no Geologist, while the marine character of the other deposits described has been frequently questioned.

Similar marine deposits have been traced up the valley of the St. Lawrence River from the ocean, as far as Lake Erie: and at Montreal, shells have been found to the height of 540 feet above the ocean. They are also found along the sea coast from the mouth

of the St. Lawrence to the extreme southern Atlantic States, generally at a less elevation. Because these fossils were found so abundantly in the valley of the St. Lawrence, the deposits were termed *Lawrentian deposits*, by M. Desor. The same designation has been applied by Sir W. E. Logan, of the Canada Geological Survey, to the oldest rocks found upon the globe, the Hypozoic. As the former sense of the term Lawrentian is now mostly obsolete, we shall use in its stead in this Report, the name *Champlain Clays*, a name which has already been used somewhat.

The extent of the Champlain Clays in Vermont is designated upon the Map, Plate II. They are widest in Chittenden and Addison Counties, and may be found anywhere in the Champlain valley below a determinate level, say 500 feet above the ocean.

Many of the facts we have derived from the labors of our predecessors, not having gathered many additions to their observations. We refer in particular to the Second Report of Prof. Adams, where there are four pages devoted to these deposits, which are called *Older Pleistocene*. His facts are of unusual interest, because of his great knowledge of the habits and nomenclature of shells. He describes the deposits of this group in their order of position, as follows:

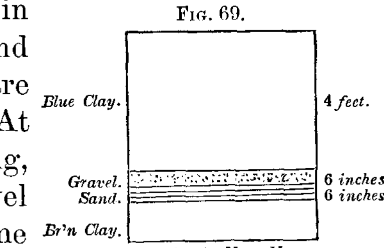
"2. Brown clay, fine sand, and loose gravel.

"1. Blue clay.

"The first three cannot be arranged in a universal order of superposition; the brown clay and fine sand appear to be for the most part local equivalents, and the gravel is variously interstratified with, or overlying either. The blue clay appears, in the innumerable examples of junction with the other deposits, to occupy the lower place, although it is by no means certain that all the blue clays of this period are contemporaneous, and anterior to all the brown clay and sand. Yet such would seem generally to be the fact. It is scarcely necessary to remark, that there are some clays, as well as many sand deposits, which owe their present situation to agencies of a date much more recent, or even of the historical period."

In describing the deposits upon the Winooski River near Burlington, we said that the sand was found overlying the clay. It is a general fact throughout the State upon the rivers, that in the higher terraces the sand is above the clay. Numerous sections in other States show the same thing. But these are fluviatile rather than oceanic deposits. It is true that the materials were brought down by rivers from the mountains, but they must have been deposited in the ocean to form such a level surface, and in this sense they may be said to be marine. Else, where did the whole of the clay in this deposit originate? The ocean cannot *produce* clay, it deposits the finely suspended materials that have been brought within its reach by rivers. The heavier deposits may have been deposited near the mouths of the rivers, while the finer matters have drifted to the south. Such seems to have been the case in the Champlain valley, for the sand in the terraces is confined to the northern part of the deposits, and near the mouths of the principal streams, while the clays are found over Chittenden and Addison Counties to the south. At the time, also, when this sea bottom deposit was accumulating, a more rapid occasional current would have brought down gravel and sand, which became interstratified with the clay in some places.

Fig. 69.



Section in New Haven.

Fig. 69 represents a section of the Champlain clays in New Haven. It illustrates the general position of the two members. Because of the great importance to Surface Geology of the exact elevation at which marine fossils have been found, we subjoin a list of heights, both of the localities of fossils and of clay beds in various parts of the State. Most of the observations were taken by Professors Adams and Thompson, the others (in Vermont) by the present Geological corps.

Place.	*Height in feet above the ocean.*	*Remarks.*
Chipman's Hill, Middlebury,	793	400 feet above the top of the clay.
Eddy of Otter Creek, Middlebury village,	323	70 feet below the top of the clay.
Prof. Adams' house, in Middlebury,	393	On the margin of the brown clay.
Hill west of Middlebury College,	470	Above the clay.
The next valley west, near the line of Middlebury and Cornwall,	356	Below the top of the clay.
Valley 1½ miles west of Middlebury College, Cornwall,	359	Below the top of the clay.
Hill one mile farther west, Cornwall,	453	Above the clay. Opposite Reuben Sampson's house.
A valley in the east part of Bridport, a little west of the Cornwall line,	159	At an old mill site.
Hill next west, near the geographical center of Bridport,	343	Covered with clay.
Hill northeast of Bridport village,	338	
Lemonfair River, near the Cornwall line, Bridport,	168	
Pot-holes in Highgate,	213	Upon rocks, near to clay.
Franklin House, Highgate Springs,	153	Upon the Champlain clays.
Village of Franklin,	433	Above the marine sands.
Tavern, East Berkshire,	458	Above the marine sands.
Tavern, Sheldon,	378	Scarcely any alluvial deposits.
Barlow's Hotel, St. Albans,	378	Below the highest elevation of the clays.
Hill in the southwest part of Cornwall, near the Four C rners,	433	Above the clay.
Hill near Shoreham village,	403	Above the clay.
Prof. Thompson's house, Burlington,	346	Upon sand and gravel.
Court House, Burlington,	202	Near marine shells.
Vermont University, Burlington,	367	Upon gravel.
Summit south of the University,	417	Upon gravel.
Summit level of the road from Nash's Point to Shelburn Bay,	190	Upon clay.
Sugar Loaf, Charlotte,	1003	Above the Chrmplain clays.
Road at the base of Sugar Loaf,	407	Above the clay.
Locality of Beluga Vermontana, Charlotte,	150	Found with Saxicava rugosa.
Sunderland Hollow (west road to Milton), Colchester,	170	
West Meeting-House, Colchester,	225	
East Meeting-House, Colchester,	223	Upon sand and clay.
Bridge over Mallett's Creek, on the west road to Milton,	105	Only fifteen feet above Lake Champlain.
Pot-holes 1½ miles northeast of Mallett's Bay,	277	
Joel Harris' house, Colchester,	325	Locality of marine shells.
Road (Barnes' Brown Iron Ore), Colchester,	258	
East road to Milton, ¼ mile north of Sunderland Hollow, Colchester,	284	
Winooski Meeting-House,	203	
Cobble Hill, Milton,	827	An insulated peak among Champlain clays.
Road at foot of Cobble Hill, Milton,	324	On sandy plain. 4th terrace of La Moille River.
Milton Falls, at Hotel,	298	Near a fine locality of shells.
Head of Great Falls, Milton,	228	On La Moille River.

Foot of Great Falls, Milton,	160	"Finest locality of shells in Chittenden Co."
Plain between Milton Falls and Checkerberry village, Milton,	302	4th terrace of La Moille River, (south side.)
Snake Hill, Milton,	912	An insulated peak above the clays.
Road at Sanderson's, southwest part of Snake Hill,	398	
Essex village,	452	Above the clays.
"Oven," Monkton, Z. T.,	756	At the same height with a bed of blue clay ½ mile east.
Locality of shells, Montreal, L. C.,	540	On Montreal Mountain.
Vergennes,	225	Upon the brown clay.
Williston,	402	Upon sand.
Richmond,	332	In the Winooski valley.
Waterbury,	425	In the Winooski valley.
Middlesex, near a clay terrace,	520	In the Winooski valley.
Montpelier (Capitol), near the foot of a thick bed of blue clay,	540	In the Winooski valley.
Northfield (Depot),	724	
Cambridge,	410	In the La Moille valley.
Johnson,	460	In the La Moille valley.
Hardwick Hollow,	720	In the La Moille valley.
Clay beds in Memphremagog valley,	778	No clay found higher than this.
Foot of 20 miles Rapids, Barnet,	486	Upon Connecticut River.
Head of do. in Lunenburg,	822	
St. Johnsbury,	585	On Passumpsic River.
Braintree,	732	On White River.
West Randolph,	678	On White River.
Royalton,	476	On White River.
White River Junction,	335	On White and Connecticut Rivers.
Hartford, near Woodstock station,	about 500	A bed of blue clay.
Woodstock,	400	On Otta Quechee River, at the terminal moraine of an extinct glacier.
Brattleboro,	160	On Connecticut River.
Newbury,	410	Clay bed.
Bennington,	432	On Waloomsac River.
Manchester,	650	On Battenkill River.
Rutland,	500	On Otter Creek.
Castleton,	475	On Castleton River.
South Troy,	740	On Missisco River.
Locality of shells, Swanton,	140	Near Charles Bullard's house.
Hill east of Middlebury,	434	Composed of brown clay.
Addison Center,	445	Brown clay.
Elgin Spring, Panton,	320	Locality of marine shells.
West side of Buck Mountain, Waltham,	383	Brown clay.
West Haven, near Whitehall,	100	Reddish clay without fossils.

This table might have been much more extended were it necessary. We hope to give a table of all the heights that we have ascertained in the State in another place, and any who wish to pursue the subjects touched upon by this list can consult that table. The objects of the one before us are these: *First*, to determine the highest elevation at which fossil shells have been observed. We see that in Vermont no one has gathered them at a greater height than 325 feet above the ocean, while near the ocean in the St. Lawrence valley, they have been collected at a height of 520 feet. *Secondly*, to determine the greatest elevation of any of these deposits of clay in the Champlain valley. The clays are found at a much higher elevation than the fossils, and the continuity of the deposits leads us to ascribe the same origin to all. This height is at Monkton Pond, where it is overlaid with marl. It is near the "oven" also, and the clay may be found abundantly in the whole region below the height of 756 feet. *Thirdly*, to ascertain, so far as possible, the altitude of other beds of clay in other parts of the State; that by comparing heights, we may learn whether a common marine origin may be ascribed to all. The highest beds of clay that were measured, were in the valley of Lake Memphremagog, in West Derby; the plain upon which the village stands being its upper limit. This was 778 feet, only twenty feet above the clay in Monkton. Others were found upon the Winooski at Waterbury, Middlesex, and Montpelier, the base of the latter being 540 feet above the ocean. On Connecticut River we do not recollect any case higher than that at Newbury, which was 410 feet above the ocean. On White River, at Hartford, one is 500 feet high. Between the altitudes of 410 and 150 feet, they are frequent between Newbury and the south line of the State. These were the only examples whose altitude was taken; nor did the propriety of the thing strike us till after the close of the field work. It is very likely that others may be found at a greater level. Other beds than these mentioned were frequent in Rutland County. *Fourthly*, to learn what towns in various parts of the State would be submerged at the various levels specified, viz: at the height of 325 feet, the highest point where the shells are found in Vermont; at the height of 520 feet, their upper limit in Canada; and at the height of the clays in western and eastern Vermont. 325 feet of elevation of oceanic waters would submerge the greater part of Franklin, Chittenden and Addison Counties, and the Connecticut River valley nearly to White River Junction; 540 feet of corresponding elevation would cover the three counties mentioned, with the greater part of Rutland County, a large tract in Bennington County, and would extend up the Connecticut above Barnet. A depression of the country to the level of the clay beds, would submerge a great part of the State, extending above Barnet on the Connecticut, above Lyndon on the Passumpsic, above Montpelier and Northfield on the Winooski, above Hardwick on the La Moille, and would cover up a part of the old sea bottoms east of the Green Mountains, besides the territory covered by the waters at the lower elevations.

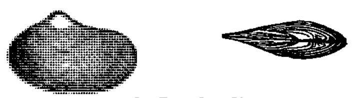
One of the most important points discovered during the whole progress of the Survey in reference to the Champlain clays, is that referred to by Prof. Adams in his division of the whole into two parts characterized by their fossils. This distinction was mentioned in his Report, but as it was not a final report, it is possible that he may have been aware of its importance. The lowest division, or the blue clay, contains only shells that inhabit deep water. The upper division, or the brown clay and the sands, contain littoral shells, etc. Hence these two deposits were made under quite different circumstances—the one in deep, and the other in shallow water. And we shall notice subsequently the fact that the oldest deposit was formed when the waters were at a greater depth, and that there is no deposit of shells of any kind between the drift and the blue clay.

I. THE BLUE CLAY.

The blue clay is stiff, argillaceous, and sometimes much indurated. It is usually found in the lowest grounds near the lake, and is rarely associated with other than clayey strata. Sometimes the texture is very fine, and it forms then a fine clay for the manufacture of

bricks. Its fossils are Leda Portlandica and Lucina flexuosa. The former was discovered in 1836, in Portland, Maine, by the Principal of the Survey, who first called the attention of geologists to these deposits. This species is probably extinct, while all the other shells of the Champlain clays found in Vermont, are now found upon our coasts, and in the deep water of Massachusetts Bay, &c. Prof. Adams says of them: "Since the industrious and persevering efforts of several able naturalists in New England have resulted in the discovery in the stomachs of fishes, of myriads of shells, of several species of Nucula without the occurrence of a single recent Nucula Portlandica, we may safely infer that this species is extinct. Lucina flexuosa, however, has been frequently found in such researches in a fresh condition. Both the L. flexuosa and the congeners of N. Portlandica inhabit deep water in fine dark blue silt, which needs only some pressure to resemble the Champlain blue clays." Both these shells are represented in Figs. 70 and 71.

FIG. 70.



Nucula Portlandica.

"The blue clays, which contain no evidence of marine origin, are insulated beds, scattered through the State, usually in valleys of various elevations. Very frequently they are overlaid with deposits of muck or of marl, or of both, in the order of clay beneath, next above marl, and then muck. One case, however, is peculiar—a large deposit in Cornwall and Shoreham, on the Lemonfair River, where blue clay is overlaid with muck, which is succeeded by blue clay and then by another deposit of muck. Probably the upper bed belongs to the newer pleistocene period, and the lower bed being in the valley of the lake, may possibly have been of marine origin.

71.

"Some of these blue clays contain a considerable percentage of carbonate of lime, and are admirably adapted for a heavy dressing of light soils.

"Some beds contain a large proportion of sand, and in them we have often seen a gradual transition from the blue clay beneath, to the fine sand above. No fossils have yet been found in these insulated beds, but claystones, of the most beautiful forms and delicate texture, are common in the finer varieties of blue clay."

II. BROWN CLAY, SILT, SAND AND GRAVEL.

The upper portion is not so constant in its lithological character as the lower. As seen by the heading, silt, sand and gravel are found associated with it, or take its place entirely. But they are all characterized by the same fossils. T. S. Hunt analyzed the brown clay, and found it composed of

Silica,	49.70
Alumina,	31.20
Peroxyd of Iron, with traces of Manganese,	6.60
Carbonate of Lime,	3.47
Carbonate of Magnesia,	2.30
Water,	6.23
	100.00

The specimen was from Middlebury. We think there is perhaps too great a difference claimed between the two kinds of clay, the blue and the brown. We have seen specimens of what we should have called brown clay in the place of the blue; and would regard the difference as accidental, perhaps from weathering, and regard the possession of characteristic fossils as the principal distinction. "The marine brown clay is most extensively distributed through Addison County, most of which, below the level of 300 feet above Lake Champlain, is covered with it. It lies directly on the drift, over blue clay, or on the lower silurian rocks. We have not yet found it above or beneath the pleistocene sands, but it appears to pass into them laterally." Its fossils are, Beluga Vermontana Thomp., the fossil grampus, "a few remains of seals and fishes," several shells such as Sanguinolaria fusca, Saxicava rugosa, Mya arenaria, and Mytilus edulis, and a sponge.

BELUGA VERMONTANA., THOMPSON.

We deem it advisable to present the account of this cetacean, which was given by Professor Thompson in his *Appendix to the History of Vermont :*

"As many rare fossils are rendered nearly valueless by the want of an accurate knowledge of their localities, and of the circumstances in which they were found, I have deemed the above-mentioned fossil, which is undoubtedly the most interesting of the organic remains yet found in Vermont, of sufficient importance to justify a minute history of its discovery and position. The discovery of this fossil took place in August, 1849. While widening an excavation for the Rutland and Burlington Railway, in the township of Charlotte, the workmen struck upon a quantity of bones, which were embedded in the clay at the depth of about eight feet below the natural surface of the ground. Some of the Irishmen remarked that they were the bones of a dead horse buried there; but little notice, however, was taken of them, till the overseer observed something peculiar in the form of several of the bones, and was thereby induced to examine them more carefully. It was soon found that the bones discovered belonged to the anterior portion of the skeleton of some unknown animal, the head of which had already been broken into fragments by the workmen, and many of the fragments carried away with the earth which had been removed. On carefully removing more of the clay, a number of vertebræ were found, extending in a line obliquely into the bank, and apparently arranged in the order in which they existed in the living animal. These vertebræ were taken out, and, together with the sternum, fragments of the head, ribs, etc., were forwarded to Burlington, and, by the kindness of Messrs. Jackson and Boardman, engineers on the railroad, were placed in my hands.

"By a careful examination of these bones, I found that they belonged to some animal with whose skeleton I was not acquainted, and that there were wanting, in order to complete the skeleton, the greater part of the head, all of the teeth, a considerable number of vertebræ and ribs, and the bones of the limbs. I was at first in some doubt whether the animal belonged to the whale family or to the saurian ; but this doubt was soon removed by a careful examination of the caudal vertebræ. These were found to have their articulating surfaces convex, and rounded in such a manner as to allow of a very extensive vertical motion of the tail, but of a very limited lateral motion. This arrangement plainly indicated that the movements of the animal in the water were effected by means of a horizontal caudal fin, and that it therefore belonged to the order of Cetacea, or Whales.

"After having carefully removed from the bones I had received the adhesive clay, in order to prevent their crumbling by exposure to the air, and secure their preservation, I saturated them with a thin solution of animal glue, and then proceeded to Charlotte in order to recover, if possible, the bones which were missing. By spending several days in the search, I succeeded in obtaining most of the anterior portion of the head, nine of the teeth, and thirteen additional vertebræ, together with the bones of one forearm, several chevron bones, and portions of ribs. From the portions of the head which I obtained, and the fragments previously received, I was able to re-construct so much of the upper and anterior portion of the head, as to exhibit distinctly its *spiracles*, or blow-holes, showing unequivocally that it belonged to the whale family. My next object was to ascertain whether it was a living, or an extinct, species of this family. Being without specimens for comparison, my only reliance for aid was Cuvier's great work on Fossil Bones. By a comparison of the fossil whale with the descriptions and figures in that work, it was found to resemble the living rather than the extinct types, and that the osteology of the head was very like that of the *Beluga leucas*, or the small northern White Whale.*

"Having collected together all the bones and fragments of the fossil within my reach, I proceeded with them to Cambridge, Mass., and submitted them to the inspection of Professor Agassiz, who confirmed the opinion I had formed respecting them, and for two days very kindly lent me his aid, and his great skill and knowledge of the subject, in their collocation and arrangement. Having, altogether, more than four-fifths of the bones of the skeleton, he was able, from the number, position and size of these, to determine the number, position and size of those which were missing, and thus to determine the size and form of the whole animal.

"The entire length of the head is 21.2 inches. The maxillary bone on the left side is mostly wanting, but on the right side it is entire, so far as to embrace the alveolar margin, which is 6.85 inches in length, and perforated for eight teeth. The corresponding alveolar margin of the lower jaw measures 5.5 inches, and is perforated for seven teeth. Hence it appears that there were sixteen teeth in the upper jaw and fourteen in the lower, making thirty in the whole. The teeth are all of one kind, being conical, with flat or rounded crowns, much worn, but, in their substance, very dense and firm. They are from one to two inches in length, with a diameter of half an inch. Only nine of the teeth were recovered, and none of these were in their places when found ; but that they were in their places up to the time the bones were discovered, is evident from the fact that while every other cavity in the bones was filled with clay, the alveoli were all empty.

"Of the vertebræ forty-one were secured, of which four were cervical, eleven dorsal, ten lumbar, and sixteen caudal. Three cervical vertebræ—the first, fifth and sixth—are evidently missing, which with the four obtained make seven, the usual number. These vertebræ are all free, not being soldered together, as in the common dolphin, and some other cetaceans.

"The second and twelfth dorsal vertebræ are missing, the whole number being thirteen. The lumbar vertebræ amount to twelve, of which the sixth and twelfth are missing. These vertebræ have all the same general form, but the lateral winged processes are much decayed and broken in some of them. The eleventh and twelfth caudal vertebræ are missing, and perhaps a nineteenth and twentieth, making the probable whole number twenty. From these statements, it will be seen that the whole number of vertebræ in the skeleton was fifty-two, eleven of which are missing. Two of the missing vertebræ were known to have been taken away after the bones were discovered. Articulating surfaces, at the meeting of the caudal vertebræ, indicate five chevron bones, of which the fourth only is wanting. The total length of the vertebral column, allowance being made for the missing vertebræ, and seventeen inches for the aggregate thickness of the fifty-one intervertebral cartilages, is one hundred and thirty-seven inches. Of this length the cervical vertebræ make ten inches, the dorsal forty, the lumbar forty-eight, and the caudal thirty-nine. The lumbar vertebræ are largest, having an average length of about four inches, with a diameter of three inches. The total length of the animal, including the head and the caudal fin, must have been about one hundred and sixty-eight inches, or fourteen feet.

"The hyoid bone and the sternum are both large and strong, in proportion to the size of the skeleton. The former measures 8.5 inches in a right line, from point to point, and the latter is fifteen inches long, from three and a half to seven wide, and on an average about one inch thick.

"The ribs are considerably decayed and broken. The longest entire rib measures just twenty-four inches along the curve. The scapula and the ulna of the right side were recovered, but all the other bones of the paddles are wanting. The height of the scapula is seven inches ; the length of the humerus five, and of the forearm four inches.

* Cuvier's Ossemens Fossiles, Vol. V, page 299 and Plate XXII, Fig. 5 and 6,—Paris edition, 1825.

"I was able to obtain the following measurements of the head, which admit of direct comparison with a part of the measurements, given by Cuvier, of the head of *Beluga leucas* :

	B. Vermontana.	*B. leucas.*
Length of the head, from the occipital condyles to the end of the snout, ...	21.2 inches.	20.9 inches.
Length of one side of the lower jaw, ...	16.5 inches.	16.5 inches.
Length of the alveolar margin, ...	8.2 inches.	7.8 inches.
Length of the symphysis, ...	3.1 inches.	3.1 inches.

"Between these measurements, it will be seen that there is a very close agreement ; but they disagree in their dental formulæ, as expressed below.

	B. Vermontana.	*B. leucas.*
Dental formulæ,	$\frac{8}{7}, \frac{8}{7}, = 30.$	$\frac{9}{9}, \frac{9}{9}, = 36.$

"They also differ in the relative width of the maxillary and intermaxillary bones, as developed on the upper side of the snout, and also in the outlines of the head.

"Since the above measurements and comparisons were made, I have had an opportunity to examine the bones of three heads of *B. leucas*, in the Hunterian Museum, in London, and an entire skeleton of the animal in the collection of Prof. Agassiz, at Cambridge, Mass. On account of the absence of Prof. Agassiz, when I visited Cambridge, a minute description of my fossil bones, with the corresponding bones of his skeleton, was not gone into, but a sufficient number of bones were compared, to leave little doubt that they belong to different species of the same genus. I have, therefore, described my Beluga under the specific name of *Vermontana*, which I gave it provisionally in my first account of the fossil."*

Prof. Thompson next introduced an elaborate account of the locality in which this fossil was found, which may be found in his *Appendix*, pp. 18 and 19. The locality is very nearly a mile and a half, by exact measurement, south of Charlotte station on R. & B. R. R., in an excavation about sixteen feet deep.—"The surface of the ground slopes to the south, and, to the depth of four feet, consists principally of sand, showing no signs of stratification. Next, below this, is a mixture of sand and clay, finely and regularly stratified, for a depth of two and a half feet, below which is a vast bed of fine blue clay, in which were observed no signs of stratification, and which appears to have been, previous to the deposit of the sand and clay above it an extensive quagmire. The fossil bones were imbedded in this clay, at an average depth below its surface of nearly two feet. The head of the skeleton was towards the northwest, was lowest, and was nearly on a level with the railway, while the posterior parts extended obliquely into the bank, towards the southeast. In the blue clay, with the bones, were found some vegetable remains, and also specimens of *Nucula* and *Saxicava*. At the surface of the blue clay were great numbers of *Mytilus edulis* and *Sanguinolaria fusca*, and the latter were scattered through the stratified sand and clay above. The locality, as ascertained by the railroad survey, is sixty feet above the mean level of Lake Champlain, and one hundred and fifty feet above the ocean."

Prof. Thompson figured several of these bones ; namely, the head, viewed from above, and on the side ; several of the teeth ; eleven of the cervical, dorsal, lumbar and caudal vertebræ ; a chevron bone ; the hyoid bone ; the sternum ; a rib, and a scapula humerus, and the bones of the forearm of the left fin in connection.

This skeleton, with the collection of Prof. Thompson, is now in the State House in Montpelier, but the separate bones have been wired together, and many of the missing bones have been supplied by models in wood. The work of restoration and fitting the bones together in, as far as possible, their natural position, was performed by Edward Hitchcock, jr., who exhibited the skeleton to the American Association for the Advancement of Science at its Springfield meeting. He made the following remarks upon it, as reported in the *New York Times* :

*American Journal of Science, Second Series, Vol. IX, p. 256.

"A Fossil Whale, found in Charlotte, Vt., in August, 1849, during the excavation for the Rutland and Burlington Railroad. It was found in blue clay, lying from ten to fourteen feet below the surface, the head almost four feet higher than the tail. The Irishmen who discovered it, supposing it to be the bones of a horse, wantonly broke many of them, and particularly the head. Enough of the head, however, was saved to give the blowholes, which are at once characteristic of the whale family. Of the thirty teeth belonging to the whale, only nine were found. These, by their worn surfaces, indicate that the animal was not a young one, but an adult. Of the fifty-two vertebræ eleven are missing, which Mr. Hitchcock had endeavored to supply by others, carved out of pine wood. The caudal vertebræ are flattened horizontally, which is another important characteristic of the whale family. The chevron bones, too, are nearly all present. The ribs are badly broken ; of the twenty-six,—the normal number,—but five were found in a perfect state. A few of the others have been wired together, and are attached to the skeleton. The sternum is very remarkable for its size and excellent preservation. It is fifteen inches in its largest diameter, and shows the indentations for the attachments of the ribs as perfectly as if it were a bone of an existing instead of a fossil whale. The anterior extremities, or fins, are also quite imperfect. The larger portion of the left fin, extending as far down as the bones of the carpus or wrist, were preserved. They well show the great strength which is so necessary in the propulsion of the animal through the water.

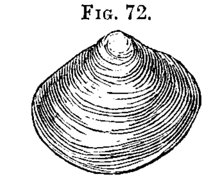
"The length of the animal, when alive, including the intervertebral substance not here represented, was about fourteen feet.

"This Vermont whale is, without doubt, of the genus Beluga ; and the specific name, *Vermontana*, was given by the late Prof. Z. Thompson, of Burlington, Vermont, who, with much labor and pains, saved these relics from destruction, and to whom, in fact, we are indebted for many of the bones, since he himself removed many of them from the railroad embankment and excavation."

We have never seen any of the remains of *seals and fishes* found in those days. Prof. Thompson states in the *Appendix to the Natural History of Vermont*, that such remains have been found, without specifying any particulars.

Sanguinolaria fusca (Fig. 72) is found abundantly in various localities on or within a few miles of the lake shore, and may be seen wherever water has washed away the banks, wells are dug, excavations made for roads and railroads, or where the land has been turned up for cultivation. "As this is now found in the bays of the New England coast, more abundantly than any other species of bivalve shells, so it is the most common of the fossils of this brown clay. It is very frequently found with the valves together, indicating that such individuals lived at or near the spot where they are found. The Mya arenaria (Fig. 73) occurs at several places, although it was by no means so generally diffused as the Sanguinolaria fusca ; but thus far we have found it only in a mixture of gravel and blue clay, more or less broken, and of less size than is common with the recent shells. It is the largest of the fossil shells ; and at some localities the number of individuals is exceedingly numerous."

Fig. 72.



Sanguinolaria fusca.

Fig. 73.

Mya arenaria.

Fig. 74.

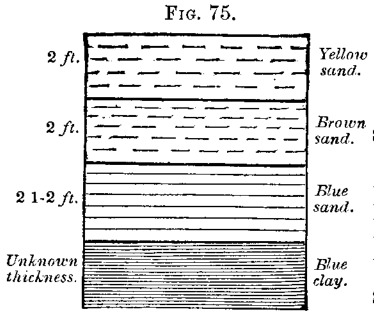
Saxicava rugosa.

The *Saxicava rugosa* (Fig. 74) is stated by our authorities to be less common than the Sanguinolaria fusca, and more frequently seen then Mya arenaria. The shell being thick and strong, is often found in a very good state of preservation. These shells, are figured, not because they are new, but that those who study Vermont Geology from our Report may be assisted.

Prof. Thompson says that "*Mytilus edulis* has been found only at a few localities ; but in some cases the individuals are quite numerous. They are seldom well preserved."

We quote further from Prof. Adams : "The marine brown clay contains more or less of carbonate of lime, and is well adapted for most agricultural purposes, although rather difficult of tillage. Concretions are common, but are usually small and irregular, either resembling septaria, or of the cylindrical type of form. The marine sands of this period occur in the vicinity of Lake Champlain, and are most abundant in Chittenden county. They extend eastward up the valleys until they reach a level above the submergence of the epoch, where they are probably of fluviatile origin. They seem to be, in the northern part of the valley of Lake Champlain, the equivalents of the brown clay in the southern parts, a current having perhaps drifted the finer materials to the south. Fossil shells, of the species Sanguinolaria fusca and Saxicava rugosa, are common, but more frequently in the lower beds near their junction with the blue clay, where they are exposed by the encroachment of Lake Champlain. A few cases are known, however, where, in strata of very coarse sand, the first named species is found abundantly at an elevation of 150 to 200 feet or more above the waters of the lake. Both species are frequently found with the valves together, and are thus proved to have lived and died in the places where they are now found."

FIG. 75.



Section of Champlain clays, St. Alban's bay.

The following is Prof. Thompson's account of the sponge found fossil in the brown clay. "While digging a well in Alburgh, about four years ago, at the depth of eleven feet, the workmen came upon a horizontal stratum of what appeared to be mats of hair. It was in quite compact clay, was about two inches thick, and extended over nearly the whole bottom of the excavation. It excited much curiosity, but very little of it was saved.—Having obtained a small quantity of it, I sent it in a letter to my friend, Prof. J. D. Dana, who pronounced it, both upon his own authority and that of Prof. Bailey, of West Point, to be *fossil marine sponge*. The specimen is in Prof. Thompson's collection in the State House.

Mr. Hall has given a section of a part of the Champlain clays, which may be seen in Fig. 75. For the first two feet there were found yellow sand and soil. For the third and fourth feet, there was found brown sand, containing marine shells. The next two and a half feet was blue sand, filled with marine shells. The remainder to an unknown depth was blue clay, which was very pure.

CHAMPLAIN CLAYS IN CHITTENDEN COUNTY.

Prof. Thompson prepared a manuscript report upon the Geology of Chittenden County, from which we extract the following account of the Champlain clays. "The pleistocene clays in the county generally lie beneath the sand, and are for the most part very finely stratified. The purer portions of the clay are lowest, and are generally blue. In these portions the fossils are rare. I have noticed them (*Nucula Portlandica*) only at two localities, one just below Winooski Falls, and the other on the bank of Laplop River half a mile east of Shelburne village. At the latter place the clay is remarkably plastic and adhesive, but contains so much carbonate of lime and magnesia, as to effervesce violently with acids. A remarkable eruption or explosion took place at this locality a few years since. By some force of water or gas beneath the bed of the clay, a portion of it appeared to have been elevated and distended, till it burst through with a considerable report, throwing large quantities of mud into the air, and bespattering the trees to a considerable distance around. And so adhesive was this mud, that it is said to have been seen upon the trees for a whole year.

"The deposits of this blue clay at the foot of the Great Falls in Milton, at the foot of the bank on the lake shore a little north of Clay Point in Colchester, and along the new road below Winooski Falls in Burlington, are among the finest I have examined.

"A large proportion of our pleistocene formation consists of a mixture of sand and clay, lying usually above the finer blue clay, and below the fine silicious sand. The fossils, though found in the sand and occasionally in the blue clay, are most abundant and best preserved in this mixture of sand and clay.—Probably nine-tenths of the shells in these formations belong to one marine species, the *Sanguinolaria fusca*, or T. Greenlandica of Prof. Emmons' New York Geological Report. The next most common species is the *Saxicava rugosa*. The localities of marine shells are too numerous to be particularized. I will, however, mention some of the most important, beginning at the south. On the road running east about half way from McNeil's landing in Charlotte, to Charlotte village, marine shells, though in not a very good state of preservation, may be seen in the ditches excavated by the side of the road. About a mile northeast from McNeil's landing, at a place called Holmes' Bay, fossil marine shells are very abundant, and are well preserved. They are embedded in the sandy clay bank, most abundant about 10 feet above the water of the bay, and they extend nearly a quarter of a mile along the shore. A little to the northeast of Nash's Point in Shelburne is a similar deposit near the lake shore, and they are also exposed by ploughing at some distance from the shore, where they appear to have been thrown into ridges by the waves, as if upon a beach. On the west side of Shelburne Bay near the south end, at the foot of a precipice, there is a locality, where, although the shells are not very abundant, the Saxicava rugosa predominates, which is not usual.

The eastern extremity of Juniper Island abounds in marine shells of several species. In Burlington they are found in at least half a dozen localities. In excavating for the Central Railroad north of the village, a stratum abounding in Sanguinolaria fusca was passed about 50 feet below the surface of the plain, and three-fourths of a mile northwest from this is the locality already mentioned, by the roadside opposite the dwelling-house of Charles Adams, Esq., lying in a layer a few inches below the surface of the ground. Another of these localities in Burlington is on the north side of Appletree Bay. The shells are found in the bank, about 25 feet above the lake.

In Colchester there are several interesting localities. One is on the south side of Colchester Point, near the extremity. Here they are most plentiful about one foot below the natural surface of the ground, and 10 feet above the lake. Another locality, and on some accounts the most interesting I have met with, is on the south side of Mallett's Bay. These are washed from a nearly perpendicular bank 25 feet high, upon which the waters of the bay are making constant encroachments, and what gives them peculiar interest is the circumstance that large numbers of them are either wholly or partially imbedded in claystones. At Clay Point there is another important locality, not only on account of the great quantity and variety of shells, but their fine state of preservation. The locality in this town two miles northeast of Mallett's Bay, on the land of Mr. Joel Harris, has already been mentioned.

The fossil shells found at all these several places are bivalve, and at most of them a large proportion have their valves united, and not a few retain their epidermis entire ; which shows, without a doubt, that they lived and died in the places where they are now found.

"The thickest part of this formation is about 200 feet."

It is not necessary to add a list of all the localities of shells that we have found in the State, as we have proposed to do, because they are so numerous. It is sufficient to say, that by digging into the earth at almost any place below 200 feet above the level of Lake Champlain, they may be found. Every island in Lake Champlain, which has any soil upon it, is particularly rich in these fossils. The finest locality that we have visited in the State, is at an excavation for the Vermont and Canada Railroad, 150 feet above the ocean, in the south part of the town of Swanton, near the house of Charles Bullard.

BEDS OF MARL.

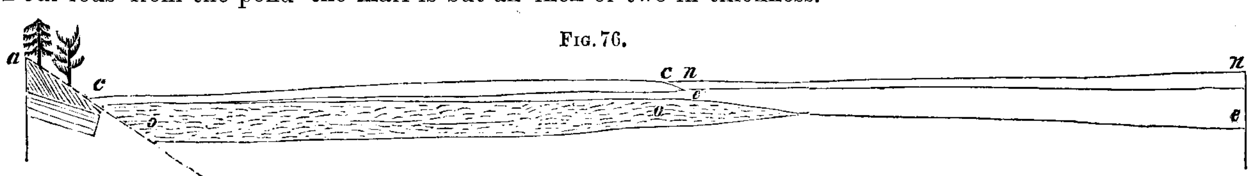
Alluvial marl is usually a fine powder consisting of carbonate of lime, clay and soluble and insoluble geine. Quantitative analysis shows, also, the presence of phosphate of lime, carbonate of magnesia and insoluble silicates in small quantities, as impurities. T. S. Hunt analyzed specimens from four different marl beds in Vermont, with the following results :

	Alburgh.	*Williamstown.*	*Peacham.*	*Monkton.*
Carbonate of lime,	82.6	89.0	83.5	79.2
Carbonate of magnesia,	2.5	4.2	1.0	2.4
Silica and traces of ox. iron and alumina,	2.6	1.0	4.2	11.2
Water and vegetable matter,	12.3	5.5	10.5	13.6
	100.0	99.7	99.2	100.1

All the marl beds in Vermont are known by the name of *shell marl;* because they have been chiefly filled with, or formed of, the shells of molluscous animals. The beds occupy basin-shaped depressions, which were once occupied by ponds, or they are found beneath existing ponds. Most of them are associated with beds of peat and other forms of organic vegetable matter. Generally the vegetable matter overlies the marl, because until a pond is nearly filled up, sphagnous mosses will not begin to grow upon its surface. But when these do begin to vegetate, the water becomes so shallow, that very little lime is brought into it, and of course the peat takes the place of the marl.

To illustrate the formation of beds of marl, we give a detailed description of one of the Vermont beds. We quote the account from the *Second Report on the Geology of Vermont, by C. B. Adams,* pages 148, 149. It is but just to quote Prof. Adams, because he first described this bed for the benefit of the State. He says: "The history of these beds of marl may be learned from the great deposit of Monkton Pond, which is now in a stage of progress most favorable for illustrating their origin. This pond contains about three hundred acres ; most of it, except the east portion which has a steeper shore, has the bottom deeply covered with marl, which was probed to the depth of eight or ten feet, without finding the bottom. About one third of the pond has less than five feet of water. The marl consists of shells more or less broken, and slimy and reddish matter. The shells are of several species, which still exist in the pond. The accompanying section (Fig. 76) represents the several deposits, beginning at the north end of the pond with the hill *a*, and extending about seventy rods into the pond ; *c c*, a muck bed ; *n n*, the pond ; *e e*, shell marl ; *o o*, blue clay. On this section, one rod from the pond, the peat is two and a half feet thick ; beneath it we find a few inches of marl ; and then blue clay, which was bored seven feet without finding the bottom. Four rods from the pond the marl is but an inch or two in thickness.

Fig. 76.



"It is obvious that we have here a type of the usual process. First, the blue clay of the older pleistocene was deposited over drift ; for although in this case we did not penetrate through it to the subjacent drift, the known examples of its immediate superposition on the drift are so numerous, that there can be little or no doubt ; then commenced the growth of the mollusca, which, although for the most part less than one quarter of an inch in diameter, and occupying much less space after comminution, have accumulated to the amount probably of 300,000 cords, or more than 6,000,000,000,000 of shells.

"Meanwhile the vegetable deposit commenced not far from the margin of the pond, and is now advancing into it over the marl, which however is still in progress—thus showing us how, of two deposits superimposed the one on the other, a part of the oldest portion of the upper one may be more ancient than the newest part of the lower bed.

"Since some of these beds are yet in progress, and others are entirely covered with several feet of peat, and that with a heavy growth of timber, their ages must be various. That they are subsequent to the blue clays of the older pleistocene appear from their very general superposition on these clays. In many cases the process therefore must have commenced with the newer pleistocene period, or possibly somewhat earlier, as it is not known they overlie the brown clay or sands. The process of filling up the ponds in many cases also has been completed, and our views of the antiquity of this period must depend on those which we adopt respecting the age of the overlying peat beds.

"The length of this period is strikingly illustrated in the Monkton marl bed. A long series of years is required to furnish shells sufficient for a single layer, and yet they have accumulated to more than ten feet in depth. Twenty thousand years is a very moderate estimate for the time required at he present rate of accumulation, and it is more likely to have exceeded this many fold."

Before describing the occurrence of the marl beds of Vermont, we would suggest a word as to their origin. A part of the marls is probably a chemical deposit. Carbonate of lime is scarcely soluble in pure water, but is abundantly soluble in water impregnated with carbonic acid. Yet the excess of acid is easily expelled, and then the salt will be deposited in a pulverulent form, unless there be some reason why it should be crystalline. As marl beds chiefly occur in the vicinity of limestone, it is easy to surmise the origin of the carbonate of lime. The tributaries convey it in solution from the ledges into the pond. There the constant evaporation of the water causes the dissolved portion to fall to the bottom. Mollusca add their shells to the mass, and at length a thick deposit will be formed. When the pond is drained or dries up, the marl may be gathered.

Upon Plate II. we have represented every marl bed in the State, of which we have any knowledge. We have learned more from the Reports of Rev. S. R. Hall, respecting their localities, than from all other sources combined. It will be seen from Plate II, that these beds are chiefly found in the eastern part of the State, or overlying the calciferous mica schist. The surface underlaid by the metamorphic schists, extending through the middle of the State, is entirely destitute of them. None of them are found except in the vicinity of calcareous rocks. The following are the localities, beginning at the southern part of the State and working northerly along the calciferous mica schist.

At Brattleboro, northwest part, perhaps passing over the line into Dummerston.

At Westminster, west part of the town, on the farm of Mr. Wilcox.

At Saxton's River Village, on the land of Mr. —— Leach, there is a bed of marl of unknown thickness, underlying a bed of peat four feet thick. The bed has been opened to a depth of four feet.

In the southeast corner of Windham there is quite an extensive bed of marl, resting upon gneiss or hornblende rock.

In West Windsor a good deposit of marl exists on the land of Samuel Myrick. It contains about two acres. And there is said to be another deposit in the neighborhood.

In Woodstock, upon the farm of Hon. C. Marsh, there is a very valuable deposit of marl, covering from twelve to fifteen acres. The marl is probably from six to ten feet thick, underlying peat. Here was a small natural pond, very much enlarged doubtless by a beaver dam ; the muck is four feet thick above the marl and of excellent quality. A supply of the best of lime may here be made for the county, and manure for the town for ages. Mortar made from this marl is unusually strong.

In Pomfret, in the north part of the town.

In East Barnard, at a pond, there is a valuable bed of marl. Considerable lime has been manufactured from it. The pond is small and will eventually dry up ; and the marl will become more available.

In Royalton, three beds. One is in the east part of the town, the others in the west part along a branch of White River. The most valuable bed is on the farm of Mr. Dewey. It was deposited in an ancient beaver pond, and is now very accessible. It can supply lime for the whole White River valley.

In the east part of Randolph.

A small deposit in Tunbridge.

Marl is found in several ponds in Brookfield. One of them is on the land of James Wilson.

In Corinth there is a valuable deposit of marl from four to six feet deep, upon the land of N. Lovewell, Esq. It lies upon blue clay and clayey sand.

In Williamstown. One upon the farm of Jason Fuller has been described in detail already, on account of the bursting of the barrier of the pond beneath which it was formerly located. We do not know whether it is the same as one described by Mr. Hall as belonging to the Messrs. Kinsman. That is represented as an "immense deposit, the largest in the State not covered by water, and adequate to supply lime to the surrounding region for many centuries." In Williamstown the facilities for the formation of marl seem to have been unusually favorable.

In Barre, in the south part of the town.

In Ryegate.

In Groton, probably in the vicinity of the ponds.

Considerable quantities of marl are found in several places in Barnet.

Several valuable and extensive deposits of marl are found in Peacham. That on the farm of Mr. Johnson is found below a thick bed of peat, and is nine feet thick, of the first quality. Another large deposit is in Ladd's Pond; and smaller deposits occur elsewhere.

Marl is found in Marshfield.

Another bed is found near the village of Calais. Another is in the west part of the town, and a third near Woodbury line at a pond.

There are two beds in Woodbury, upon the borders of ponds.

There is a bed of marl in the east part of Cabot.

Marl is found in several ponds in Danville. In Keyser's Pond the quantity is large; and in the east part of the town lime has been manufactured from another bed.

There are two beds, at least, in St. Johnsbury. One of them is on the farm of Hon. E. Paddock, which is quite large.

In Walden, two or more beds. One of them is on the borders of Lyford's Pond, where the amount is almost inexhaustible.

In Hardwick, a very valuable deposit of marl occurs on the farm of Rev. J. Underwood, and another on the farm of Mr. W. Bailey.

In Greensboro there is a bed of marl, of good quality but not very extensive, on the farm of Mr. Field.

In Glover, there is a large deposit of marl in the bed of Mud Pond, which was drained in 1810, when the famous pond above run away to Lake Memphremagog. A second is upon Parker's Pond, and a third in the east part of the town.

In Craftsbury, inexhaustible amount of marl in Great Hosmer, Little Hosmer and Duck Ponds.

In Albany, on the farm of Zuar Rowell, east of Great Hosmer Pond, is a very valuable bed of marl, beneath 4 feet of peat. The marl varies from 4 to 8 feet thick, where examined, and covers from six to ten acres. Both the peat and the marl are of excellent quality. The deposits are in what was anciently a natural pond, enlarged by a beaver dam, now entirely filled up. On the land of Mr. G. W. Powers, in the southeast part of the town, is a beaver meadow, upon which is a bed of peat 5 feet thick, covering five or six acres; and beneath the peat is a bed of marl, resting upon gravel and blue clay. This marl is mixed with clay in some places. Half a mile north of this, upon the land of Mr. Orne, there is another bed of marl, of fifteen or twenty acres area. The overlying peat is from 2 to 5, and the marl from 8 to 10 feet thick. The marl is of excellent quality, and is upon the borders of a pond. The pond may easily be drained. It now covers but a few acres, and will eventually be entirely filled up by the agencies which have already diminished it to a tenth part of its former size. In the northeast part of the town there is a large beaver meadow, covering from one to two hundred acres, beneath which marl is supposed to exist.

In Lyndon two beds, one in the north, the other in the south part of that town.

Mr. J. E. Smith, of Provincetown, Mass., informs us that upon his father's farm in East Burke there is a bed of Marl.

In Sutton, north part.

In Sheffield, north part.

In Westmore, south of Willoughby Lake.

In Barton, in the east part of the town.

In the north corner of Brownington.

There is an extensive bed of marl on the low lands in the north part of Coventry, near the entrance of Barton River into Lake Memphremagog.

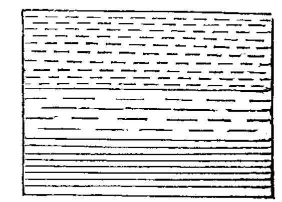
A large supply of marl may be found in at least two places in Charleston, in the west part of the town. One of them is upon Pensioner's Pond.

In Salem, upon the west side of Salem Pond.

In the west part of Morgan.

In Holland there are two or more beds of marl in the west part of the town, and there is one in the east part of the town. One of them is on the road between Morgan and Stanstead, C. E., upon a beaver meadow from five to seven acres in extent. The marl is beneath peat, and is from 2 to 3 feet thick. When the peat is 2 feet thick the marl beneath is also 2 feet thick, and when the peat is 3 feet thick the marl beneath is three feet thick. The marl rests upon blue clay and a clayey gravel. This is one of the best known beds of marl in the State.

Fig. 77.



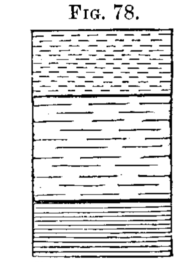
Marl Bed in Derby.

Fig. 77 represents the peat, marl, and underlying sand of a marl bed in Derby. There are two beds of marl in the town. The one on the land of Mr. Willey, near Derby Center, is one of the largest in the State.

The deposit in Monkton has already been described. It rests upon the Red Sandrock.

In Grand Isle, upon the land of Mr. Pearl, in the northeast part of the town about half a mile from Lake Champlain, there is a bed of marl. It occupies a basin about forty rods long and twelve wide, 100 feet above the lake. Peat 2 feet thick overlies it, and its thickness was not ascertained. It appears to be entirely composed of shells, of which the greater part belong to the genus *Planorbis*.

Fig. 78.



Sec. in Alburgh.

In the northwest part of Alburgh, upon the farm of Judge Lyman, there is a bed of marl covering forty acres of surface. Fig. 78 represents its position and thickness. The blue clay beneath is the upper member of the Champlain clays. The locality is very near Canada line, about one mile from Lake Champlain. The upper stratum of the marl, in contact with the peat, is composed of shells, mostly entire, of the genera Planorbis and Lymnæa. The shells become more broken or pulverized in descending into the bed, and at the depth of 2 feet few are seen.

Messrs. Hall and Thompson mention a bed of marl in Highgate, but without specifying the locality particularly.

We doubt not that the number of marl beds in Vermont is more than double of this catalogue.

Genera of mollusca inhabiting the marl ponds. We regret very much the loss of the information concerning the mollusca inhabiting the ponds beneath which the beds of marl are found, which was obtained by Prof. Adams. No man was better qualified to name these different species, and draw from the facts interesting inferences. We have reason to suppose that his information on this subject, if made public, would have contributed largely to our knowledge on this important subject. In Monkton Pond alone, he found eleven species. Since the re-organization of the Survey in 1857, no one has examined the beds of marl with such care as was exercised by Mr. Hall ten years previous. All the specimens he procured, however, from which we might have drawn interesting conclusions, were destroyed in the burning of the State House in 1857.

All the shells which are found in the beds of marl, belong to living animals. They belong chiefly to the following genera of mollusca: Paludina, Lymnæa, Physa, Planorbis, Pupa and Cyclas. We have no means of saying how many species of these genera are common.

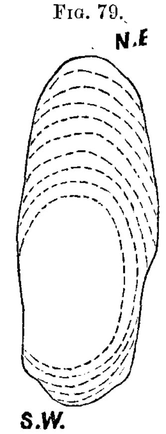
SILICIOUS INFUSORIA.

Many ponds are inhabited by myriads of microscopic animalcules, whose skeletons, when the animals die, fall to the bottom, and in process of time form deposits of fine silicious earth, several feet thick. The earth consists mostly of silica, with a small per cent. of iron. As the marl originated from the shells or earthy portions of mollusca, so this earth has originated from the remains of animalcules. Hence the general mode of the formation of both classes of deposits is the same.

A few localities of infusorial earth have been discovered in Vermont; but probably not a tithe of what may be found upon a careful examination. The account which we give is compiled from the results of our predecessors, particularly the second Report on the Geology of Vermont by Prof. Adams.

"The most extensive deposit in the State is at the bottom of Hosmer's Pond in Peacham. It is in the southwest corner of the town, containing from 250 to 300 acres. The southwest part is from two to six feet deep. Over the greater part of the bottom, generally above a deposit of peat, but sometimes resting on blue clay, is the deposit of infusorial silica. When the bottom is gravelly, none is seen. The peat varies in thickness below the infusorial deposit.— In a few places peat covers it for an inch or two, but generally a short grass grows upon it. In a few places "eel-grass" is seen growing on it. The average thickness of the deposit is six inches. If it covers 200 acres of the pond, there are not far from 1,904,000 cubic feet, or over 14,000 cords!— If every cubic inch contains ten billions, the total number in this deposit of animalcular shells cannot be less than 20,000,000,000,000,000."

Fig. 79.

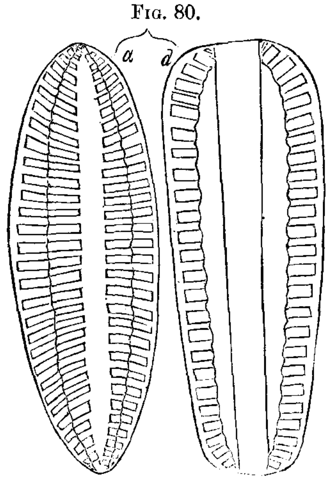


Hosmer's Pond.

Fig. 79 shows the position and shape of Hosmer's Pond. That part of the pond in the figure which is dotted was alone examined, because the water was too deep in the central part to be probed by Mr. Hall's auger.

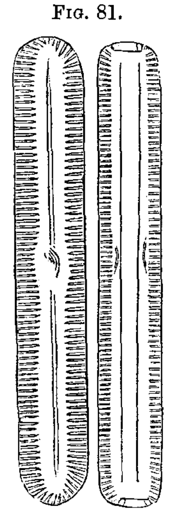
Infusorial Forms from Hosmer's Pond, Peacham; magnified 270 *diameters.*

Fig. 80.



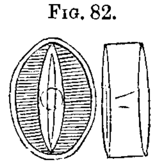
Surirella splendida.

Fig. 81.



Pinnularia viridis.

Fig. 82.



Pinnularia Suecica.

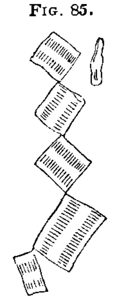
Fig. 83.

Eunotia tetradon

Fig. 84.

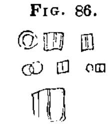
Eunotia decaodon.

Fig. 85.



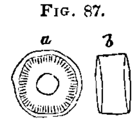
Tabellaria trinodis.

Fig. 86.



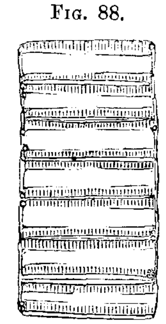
Gaillionella varians.

Fig. 87.



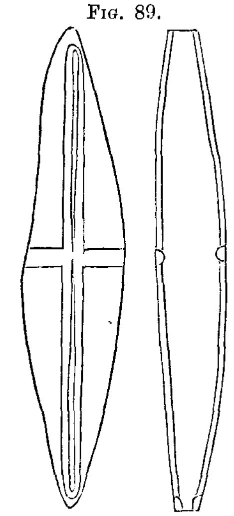
Gaillion ella distans.

Fig. 88.



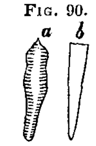
Himantidium arcus.

Fig. 89.



Stauroneis Baileyi.

Fig. 90.

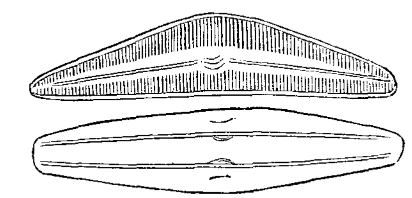


Gomphonema acuminatum.

Fig. 94.

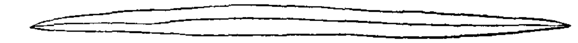
Eunotia monodon.

Fig. 91.



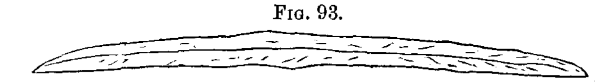
Cocconema cymbiforme.

Fig. 92.



Spongilla lacustris.

Fig. 93.



Spongilla erinaceus.

Some of the specimens from Peacham were sent to the late Professor J. W. Bailey, of West Point, New York, who made the following remarks concerning them:

"*West Point, N. Y., Jan.* 26, 1846.

Prof. C. B. Adams:

My Dear Sir,—The specimen which you sent me for examination, from Peacham, Vt., proves to be, as you supposed, a mass of infusorial matter. It presents all the usual characters of the deposits now well known to exist under almost every peat bog in the country. It is chiefly remarkable for abounding in very perfect carapaces of that beautiful animalcule *Surirella splendida*, of Ehrenberg, [Fig. 80.] Among the other forms which I recognized, are the following:

Pinnularia viridis,	Ehr.	Fig. 81
" Suecica,	Ehr.	Fig. 82
Eunotia tetraodon,	Ehr.	Fig. 83
" decaodon,	Ehr.	Fig. 84
Tabellaria trinodis,	Ehr.	Fig. 85
Gaillionella varians,	Ehr.	Fig. 86
" distans,	Ehr.	Fig. 87
Himantidium arcus,	Ehr.	Fig. 88
Stauroneis Baileyi,	Ehr.	Fig. 89
Gomphonema acuminatum,	Ehr.	Fig. 90
Cocconema cymbiforme,	Ehr.	Fig. 91
Spongilla lacustris,	Ehr.	Fig. 92
" erinaceus,	Ehr.	Fig. 93

"There are many other species present for which the names cannot be determined until we receive Ehrenberg's forthcoming work, in which all the known species are to be figured and described."

In Maidstone there is another deposit of infusorial silica, concerning which Prof. Bailey made the following remarks:

"*West Point, Feb.* 16, 1846.

Prof. C. B. Adams:

My Dear Sir,—Your interesting letter with its inclosed specimens came safely to hand, and I have given them a somewhat hasty examination, which has afforded the following results.

"The most interesting specimen in the infusorial marl from Maidstone, although not so white as many infusorial deposits, it is almost wholly composed of shields of animalcules, and is quite free from sand or other inorganic matter. The principal species present are these, many of which are almost ubiquitous, viz:

Pinnularia viridis,	Ehr.	abundant.	Fig. 81
" viridula,	Ehr.		
" pachyptera,	Ehr.	rare.	
Stauroneis Baileyi	Ehr.		Fig. 89
Synedra ulna,			
Himantidium arcus,	Ehr.		Fig. 88
Gomphonema acuminatum, rare in this specimen.			Fig. 90
Eunotia monodon, etc.			see Fig. 94

"These are the largest forms, and most of them are quite abundant, but the great mass is made up of frustules of the minute Gaillionella varians of Ehrenberg, whose size rarely exceeds one twenty-five hundredths of an inch. Now, although 'figures will not lie,' they yet lead to almost incredible results, when we calculate how many of these minute but perfect organisms occur in a single cubic inch of this deposit.—You may go over the calculation, and correct the result if wrong.

$2500 \times 2500 = 6{,}250{,}000$; Six millions two hundred and fifty thousand in a square inch.

$2500 \times 2500 \times 2500 = 15{,}625{,}000{,}000$; Fifteen thousand six hundred and twenty-five millions in a cubic inch.

"Yet I suppose your locality contains many thousands, not merely of cubic inches, but of cubic feet of matter equally rich in animalcular remains. This specimen also contains the fossil pollen of pine and other trees.

Yours, most truly,
J. W. BAILEY."

There is another small deposit of infusorial silica in Westmore, south of Willoughby Lake. All the above species, called animalcules, are now regarded, we believe, as microscopic plants.

PEAT.

Peat is formed in bogs and marshes by the accumulation of vegetable matter, especially the constantly decaying roots of the sphagnous moss. It is often deposited upon the top of marl, as has been mentioned on a previous page. The number of peat beds in Vermont is so great that we have not endeavored to enumerate them. They may be found in every town in the State. We will, however, mention those of special interest, mostly from the observations of Rev. S. R. Hall.

The relations of peat to marl are shown in Fig. 78. The peat is five feet thick, and is covered with a growth of timber, consisting of cedar, black ash, tamarack, spruce and pine.

In Albany, on the farm of Zuar Rowell, east of Great Hosmer's Pond, overlying marl is a bed of peat four feet thick, covering from six to ten acres. There is about 1500 cords of peat on each acre. On the land of G. W. Powers, in the southeast part of the town, half a mile north upon Mr. Orne's farm, in the northeast part of the town, on land of Mr. Church, Mr. Hovey, etc., there is a great amount of peat. Near the new church there is a bed of peat evolving sulphureted hydrogen when disturbed.

Peat is also described as abundant in the towns of Andover, Barnet, Barre, Barton, Berlin, Bethel, Bradford, Brattleboro, Bridgewater, Brookfield, Brownington, Calais, Cavendish, Chelsea, Chester, Corinth, Coventry, Craftsbury, Danville, Derby (see Fig. 77), Dummerston, Eden, Elmore, Glover, Greensboro, Hancock, Hardwick, Hartford, Holland, Hydepark, Jamaica, Londonderry, Lowell, Ludlow, Marshfield, Montpelier, Moretown, Morristown, Newfane, Norwich, Peacham, Plymouth, Putney, Pownal, Randolph, Rochester, Rockingham, Royalton, Ryegate, St. Johnsbury, Springfield, Thetford, Townshend, Troy, Waitsfield, Walden, Wardsboro, Warren, Washington, Waterbury, Waterford, Weathersfield, Westminster, Westmore, Williamstown, Windsor, Woodbury, Woodstock, Wolcott and Worcester. If any one wishes for the particulars concerning these beds, they will be found described as *muck* in the Second Geological Report of Prof. Adams.

CALCAREOUS DEPOSITS FROM WATER.

Most of the mineral springs in the State deposit more or less carbonate of lime in the form of tufa. In the northeast part of Middlebury are several associated springs which deposit a small amount of very porous tufa. The mineral springs of Williamstown deposit a more solid tufa (No. $\frac{8}{28}$ in the Cabinet), as does also a spring in the north part of Monkton, in which abundant bubbles of carbonic acid gas are constantly rising with much vivacity. These tufas consist chiefly of slender anastomosing stems, which are more or less covered with minute delicate spines and tubercles.

Examples are more common, in which, without any constant spring, tufa accumulates at the base and sides of hills and cliffs of calcareous and calciferous rocks. On the sides of the Lonerock Point, Burlington, and along the same bluff as far as St. Albans, it collects in the crevices of the precipice, and occasionally incrusts and fills pieces of delicate moss. On the west side of a cliff of Red Sandrock, in the south part of Snake Mountain, Bridport, near the house of a Mr. Frost, is a deposit, which has been called

'cinders,' and had been erroneously supposed to be of some economical importance. Numerous irregular cavities in it have a mammillary surface, and a number of small angular stones are imbedded in it, forming a kind of breccia. A similar case occurs at Mallett's Bay, Colchester. At the base of a ledge of silicious limestone east of Mr. Church's house in Highgate, is a very solid tufa, with the surfaces mammillary or densely covered with very minute tubercular and botryoidal stalactites. In some cases, as in Derby and at Mallett's Bay, the tufa contains so much gravel as to approximate to a conglomerate.

Stalactites are common in most of the numerous caves in the Eolian limestone. Some of them are immense, being three feet or more in diameter. In the caves that are most visited, the stalactites have mostly been broken off by visitors.

ALLUVIAL CONGLOMERATES.

In Pownal, half a mile north of the State line, and upon the northeast bank of Hoosac River, is an interesting example of a calciferous conglomerate, and sandstone. The process of consolidation seems to be going on every day; the cement being the calcareous matter derived from subjacent limestones. (See $\frac{1}{93}$ in Cabinet.)

There is a similar but harder conglomerate cemented by lime, in Westford, on the land of Dr. Haines.

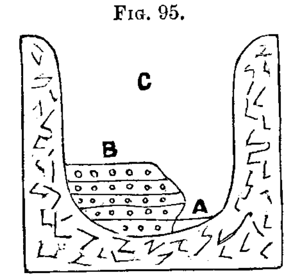
Similar conglomerates may be found in several places in Pittsford.

Other conglomerates are cemented by the hydrated peroxyd of iron. A ferruginous conglomerate is described by Prof. Adams, in Warren, where it was found by Mr. William B. Tyler, about two miles west of his house, having been revealed by a brook. In the east part of the town we saw another example, associated with calcareous tufa.

So great an amount of consolidated drift was found in Shaftsbury and other towns in the great Taconic valley, that we are disposed to believe that a great part of the coarser deposits in the western part of the State, which are located upon highly ferruginous limestone, will be found to be consolidated.

There is a locality of interest, of this kind, in Dover. It is represented in Fig. 95. In a ferruginous serpentine, Rock river has cut a deep gorge, C, with precipitous sides. In the bottom of this gorge is a consolidated conglomerate, B, as tough as new red sandstone, and containing many large pebbles. The river has cut through this conglomerate at A. Hence in this gorge there has been a double amount of erosion performed. First the gorge itself was excavated from solid rock. Then the gorge was filled, perhaps entirely, with coarse gravel of the drift period. By the time that the ocean had retired, the gravel had been cemented together by the peroxyd of iron decomposing from the serpentine, so that the river must wear it away before it can resume its former position. The conglomerate is now mostly worn away.

FIG. 95.



MANGANESIAN DEPOSITS.

"*Manganese wad* is found in reniform masses in a swamp in Moretown; also in the east part of Brandon and in Lowell, in small concretions. In some instances masses of sand are cemented by this mineral, forming sandstones which are less coherent than those of calcareous or of ferruginous origin. Traces of hydrate of iron are more or less distinct on the surface. In the east part of Warren, Dr. Thresher procured specimens, which contain a large portion of manganese. In the northeast part of Benson, there is a bed of this sandstone in a hill side. In Stowe, on land of Mr J. Downer, it occurs with a firmer texture."

REMAINS OF TERRESTRIAL MAMMALIA IN ALLUVIUM.

The most important mammalian fossil of this kind is the elephant from Mt. Holly. We give Professor Thompson's description of it:

"*Elephas primogenius, Blumenbach.* It is a remarkable fact, that in making the Rutland and Burlington Railroad, which extends from Burlington to Bellows Falls, two of the most interesting fossils ever found in New England were brought to light. These were the remains of an elephant and a whale. The former were found in Mt. Holly, in 1848, and the latter in Charlotte, in 1849.

"The Rutland and Burlington Railroad crosses the Green Mountains in the township of Mt. Holly, at an elevation of 1415 feet above the level of the ocean, and the bones of the fossil elephant were found at that height. It is in a peat bed east of the summit station that these bones are found. The basin in which the peat is situated appears to have been originally filled with water, and to have been a favorite resort for beaver, a large proportion of the materials which formed the lower part of the peat consisting of billets of wood, about eighteen inches long, which had been cut off at both ends, drawn into the water and divested of the bark by the beaver, for food. The peat was fifteen feet deep before the excavation was made for the railroad.

"In making this excavation, the workmen found at the bottom of the bed, resting upon gravel which separated it from the rock below, a huge tooth. The depth of the peat at that place was eleven feet. Soon afterwards one of the tusks was found, about eighty feet from the place of the tooth above mentioned, which was a grinder. Subsequently the other tusk and several of the bones of the animal were found near the same place. These bones and teeth were submitted to the inspection of Professor Agassiz, who pronounced them to be an extinct species of elephant. The directors of the R. & B. R. R., to whom they belong, design to have them placed in the museum of the University of Vermont, for preservation, and for the illustration of our fossil geology.

"The grinder is in an excellent state of preservation, and weighed eight pounds, and the length of its grinding surface is about eight inches. The tusks are somewhat decayed, and one of them badly broken. The cord, drawn in a straight line from the base to the point of the most perfect tusk, measures sixty inches, and the longest perpendicular, let fall from that to the inner curve of the tusk, measures nineteen inches. The length of the tusk, measured along the curve on the outer surface, is eighty inches, and its greatest circumference twelve inches. The circumference has diminished very much, since the tusk was taken from the peat bed, on account of shrinkage in drying, and several longitudinal cracks have been found in it, extending through its whole length, and it was found necessary to wind it with wire to prevent it from splitting to pieces."

In 1858 remains of another elephant were found in Richmond, which are now in the Cabinet of Vermont University.

The fossil ham of some ruminant has been found in Hartford; and the ham of a deer in the alluvium of Grand Isle; the latter specimen is in the Cabinet of Vermont University.

Other fossils are found in a cave at Chittenden,—the bones of small animals, such as are now alive.

HEIGHTS OF TERRACES, BEACHES, &c., IN VERMONT, ABOVE THE BODIES OF WATER TO WHICH THEY ARE CONTIGUOUS, AND ABOVE THE OCEAN. HEIGHTS IN ENGLISH FEET.

	1	2	3	4	5	6	7	8	9	10
On Connecticut River.										
East Hartford, Ct., highest terrace, L,		40 61								
East Windsor, Ct., highest terrace, L,		71 96								
Springfield, Mass., highest terrace, L,					136 200					
Willimansett, Mass., highest terrace, L,		194 268								
South Hadley, Mass., highest terrace, A,		193 298								
Pelham, Mass., highest terrace, L,										383 483
Turner's Falls, Mass., highest terrace, L,				150 344						
Northfield (south part), Mass., terraces, L,	24 224	90 290	131 231	Unk.						
Northfield (north part), Mass., terraces, L,	24 224	87 287	112 312							
Hinsdale, N. H., south side of Ashuelot river, near its mouth, L,	9 215	14 222	36 244	66 274	150 358					
Hinsdale, N. H., south side of Ashuelot river, L,	7 215	14 222	37 245	73 281	162 370					
Hinsdale, N. H., on Connecticut river, beyond the village, L,	21 231	96 306	159 361	Unk.						
Vernon, north part, L,	21 234	38 251	107 320	237 450						
Brattleboro, mouth of Whetstone Brook, towards the southwest, L,	20 234	74 288	86 300	118 332	165 379	200 414				
Brattleboro, mouth of West river, across the village southwest, L,	25 239	47 261	58 272	70 284	80 294	100 314	114 328	152 246	221 435	
Brattleboro, on Whetstone Brook, L,	8 222	14 228	23 237	44 258	56 270	83 297	102 316	138 352	153 367	Unk.
West Brattleboro, on Whetstone Brook, A,				401	Above	Conn.	River.			
Westminster, terraces, L,	24 255	94 325	139 370	171 402						
Langdon, N. H., mouth of Cold River, south side, L,	16 251	94 329	243 478							
Westminster, near Bellows Falls, opposite Cold river, L,	26 261	34 269	38 273	83 318	117 352	138 373	161 396	226 461		
Bellows Falls, above the Falls,	41 327	122 408								
Weathersfield, near north town line, A,	40 328	56 344	80 368	115 403	140 428	155 443				
Windsor, north of the village, A,	8 289	30 320	65 355	73 363	112 402	150 440	207 497			
North Hartland, mouth of Otta Quechee river, A,	8 313	30 335	46 351	64 369	134 439	153 458				
White River Junction, mouth of White river, A,	15 335	27 347	63 383	144 464	209 529					
Norwich village, A, (terrace,)	75 400									
Newbury village, A,				94 420						

	1	2	3	4	5	6	7	8	9	10
On Black River.										
Proctorsville, north side, A,	17 895	68 946	135 1013	150 1028						
Proctorsville, south side, A,	14 892	30 908	48 926	82 960	110 988	150 1028				
On Broad Brook.										
Guilford (Algiers), high terrrace, A,			286 490	Above	Conn.	River,	at	S. Ver	non.	
On Green River.										
West Guilford, A,		692 896	Above	Conn.	River.					
On Passumpsic River.										
St. Johnsbury Plain, A,				585	Above	Ocean				
Lyndon,		735	Above	Ocean						
On Deerfield River.										
Hartwellville, west branch, A,	1700	Above	Ocean							
On Hoosac River.										
Pownal, on north side, A, above river,	6	16	36	102	307					
On Winooski River.										
Burlington, Court-House,				112 202						
Essex, north side, A,				260 350	291 381	Above	Lake	Cham	plain	
On La Moille River.										
Johnson, north side, A,				190 660						
Johnson, east of village, A,						277 737				
Hardwick, west part, A,				380 1100						
Georgia Plains, A,				132 411						
Milton, A,				132 411						
On Battenkill River.										
West Arlington, A,				349	Above	river.				
On Poultney River.										
West Haven, (Adams,)			150	Above	river.					
On Lewis Creek.										
S. E. Hinesburg, A,					570 660	Above	Lake	Cham	plain.	
S. E. Hinesburg, at height of land, A,	652 742	702 792	Above	Lake	Cham	plain.				
On Huntington River.										
Huntington, (old bed of river), A,	85 714	105 731								

	1	2	3	4	5	6	7	8	9	10
On Lake Memphremagog.										
East side of the Lake, A,			83 778			276 971				
*SEA BEACHES IN NEW ENGLAND.										
On Connecticut River.										
Lyme, Ct., L,	14									
East Lyme, Ct., L,	19									
Pelham, Mass., A,	567 672	921 1029	1049 1151							
Shutesbury, Mass., L,	1053 1167	1103 1217								
Amherst, Mass., L,	329 437									
Whateley, north part, Mass., A,	690 795									
Conway (Shirkshire), Mass., A,	928 1033									
North Ashfield, Mass., A,	976 1031	1216 1321								
Heath, Mass., L,	1438 1561									
Rockingham (estimated),	600	to	700							
Norwich, north part, A,	967 1287	1017 1337								
Copperas Hill, Strafford, A,	1015 1340									
Thetford Hill, A,	354 878									
Newbury, A,	1162 1488									
East Corinth, A,	1239									
Waterford, estimated,	525	to	700							
On other Rivers in Vermont.										
Shaftsbury Center, A,	643									
Pittsford and Brandon, on Otter Creek, estimated,	600	to	800							
West Hancock, A,	2196									
On La Moille River, A,	1240									
Elmore and Woodbury, on same river, A,	1240									
West Fairfax, on same river, A,	440									
Victory, Passumpsic valley, estimated,	1738									
Newport, Memphremagog valley, A,	365 1060									
Salem, same valley, A,	276 971									
Brownington, same valley, A,	579 1274									
Elsewhere in New England.										
White Mt. Notch, White Mt. House, N. H. (Guyot),	1569									
Franconia Notch, N. H., A, (Ct. river),	1524 1930	2043 2449	2259 2665							
Deerfield Mt., Mass., L,	407 537									
Peru, Mass., L,	2022									

* Heights above the ocean given, when only one figure is used.

	1	2	3	4	5	6	7	8	9	10
Washington, Mass., summit level of Western Railroad, L,	46 1590									
Between Albany and Schenectady, N. Y., on Hudson River,	335									
On Western Railroad, east of Hudson River, A,	330	554	642	890	1111	1378	1590			
MORAINE TERRACES.										
Norwich, A,	712 1032									
Strafford, A,	712 1032	172 492								
Ripton, A,	1070									
SEA BOTTOMS.										
Washington and Williamstown, A,	700	to	1600							
South Troy, A,	740	to	1030							
Highest elevation of Champlain clays,	756									
Fossil marine shells in Vermont,	100	to	400							
Fossil marine shells at Montreal,	520									
Clay beds in Memphremagog valley,	778									

We have given above a Tabular veiw of all the terraces and beaches in the State, that we have measured, or that we could find recorded by other authorities. The letter A annexed to the localities, indicates that the heights were obtained by the Aneroid Barometer. L signifies, in the same position, that the heights were obtained by Leveling. All those ascertained by leveling, were taken from the *Illustrations of Surface Geology*. A few other beaches from other parts of New England have been added, for the sake of comparison with those in Vermont. When there are two figures against each locality, and connected by a brace, the upper one denotes the height of the Beach or Terrace above the stream to which it is contiguous ; and the lower one denotes its height above the ocean. When there is only one figure present, it may be the height above either of these levels, and the particular one in each instance is specified by some additional explanation. The importance of tabulated heights of Terraces and Beaches cannot be over-estimated. For by them we may learn what beaches, in different parts of the county, have the same height above the ocean ; and may discover whether there is any such occurence of both terraces and beaches at successive levels all over the State and country, as to sustain the theories of most geologists, who maintain that they were formed by paroxysmal movements of the continent upwards, and it will form an excellent standard by which to test the truth of all theories respecting their origin and distribution.

CONCLUSIONS FROM THE FACTS PRESENTED.

It has been already stated that, lithologically, alluvium may be divided into two parts—Drift, and Modified Drift; and chronologically into four periods, in each of which the continent was differently situated in respect to the ocean, viz., the *drift period*, when the continent was under water at its greatest depth ; the *beach period*, when it began to emerge ; the *terrace period*, when the continent rose to nearly its present situation, and the *historic* or present period. The oldest of these periods has already been dwelt upon fully. We have seen that the continent began to sink in the newer pliocene period, until the approach of the icebergs or some other cause exterminated the life of that period in Vermont, and it continued to sink, till it had sunk to a depth of 5,000 feet. Next the movement was upward, and after it had risen about 2,400 feet, beaches began to form on the highest mountains. At this point we take up the history and endeavor to decipher the hieroglyphics of nature. The principal, by his reasonings upon the facts of drift, may be said to have plunged the whole State under water, and it will be our province to restore it again to the day light, especially as he has shown it to have commenced to rise. We shall consider the submersion of the continent as a fixed fact, and shall therefore make no attempts to prove it formally. Our province will be to state how the beaches, &c. were formed by the action of oceanic and fluviatile agencies during the upward movement. A very general statement of our theory is the following: Drift agencies, when the continent was sinking, while at its greatest depth, and while rising 2,400 feet, rounded, scratched, and polished the ledges and spread the materials thus derived over the bed of the ocean. These materials would be more or less angular, crushed though somewhat rounded; and for the most part without well marked lines of stratification. The great icebergs which had been sweeping over the country, at the opening of the beach period would be stranded; and the high hills capped by drift accumulations would just show their heads above the water. The action of the water would wash the drift detritus, rounding the fragments, at first imperfectly, sorting the materials and arranging them into strata, in limited localities. These constitute the highest beaches. A gradual rise of the continent would show beaches at lower levels, while over the lower hills icebergs would still be grating and scarring.

Next, we suppose the land to have risen so much that the great valleys are seen in outline; small tributaries bring their deposits of gravel and sand into the larger valleys, deriving them from the drift and beaches, and these greatly modifying the character of the drift. These constitute the higher terraces. As the continent continued to rise, the lower terraces would be formed from the ruins of drift, beaches and older terraces. In consequence of the equable rise, the terraces are found at various levels: not even being of the same height on both sides of the same valley, and the lower ones exceedingly variable in number. The action of tributaries upon the great terraces of the large streams would form numerous small terraces from them, from six to ten or more in number. In other words, the gradual drainage of the continent has produced all the multiplied and various phenomena of surface geology, mostly from the materials broken off from the ledges by icebergs, glaciers, etc. We will trace the progress of these phenomena more at length, endeavoring to establish certain points and drawing from them appropriate conclusions.

PERIOD OF BEACHES AND OLDER SEA BOTTOMS.

1. All alluvial beaches, terraces, sea bottoms, etc., lie above the coarse unstratified and unmodified drift, as well as above striated, grooved and embossed ledges connected with drift. We may specify cases of this sort in the Winooski valley, where terraces were found overlying striæ. It is evident, hence, that the striæ were formed before the terraces were deposited. We would not assert that no drift shows evidence of stratification. It is common to find limited beds of sand, clay and gravel in the midst of coarse materials, and sometimes we find masses of coarse irregular detritus and scattered blocks, over deposits that are distinctly sorted and stratified. But as a general fact, the sorted and stratified materials lie above the drift. Indeed it is not easy in every case to draw an exact line between the unmodified drift and the modified accumulations. They pass into each other by insensible gradations.

2. The successive beaches and terraces, as we descend from the highest to the lowest, in any valley, seem to have been produced by the continued repetition of essentially the same agencies by which the materials — originally coarse drift — have been made finer and finer, and have been more carefully sorted and arranged into more and more perfect terraces and beaches.

3. The largest part of the materials constituting the terraces, beaches, &c., is modified drift, that is, the fragments of rocks, &c., torn from the ledges by drift agencies, washed, rounded and worn down by water.

This position is established by the first proposition, that all the phenomena of drift are found lying beneath the various forms of modified drift. The striæ occur in valleys as well as on the hills, sometimes at the very water's edge. In some parts of the country there may have been a greater amount of rock eroded since the drift period; but nowhere an amount that will compare with the quantity that had been removed previously. At Bellows Falls, upon Connecticut River, the rocks at the top of the falls, even to the water's edge, exhibit striæ and other marks of drift, although the cataract has undoubtedly receded considerably at this spot since that force acted. At Brattleboro the slate on the west side of the river shows drift furrows only a few feet above the river. Here too was once a gorge; but it was worn out earlier than the drift period. At Fairfax, upon the La Moille River, striæ may be seen within five feet of the surface of the water; while in Wolcott evidences of water action, such as pot-holes, may be found fifty feet above the river before striæ are discovered. And in Wallingford, upon Otter Creek, may be seen a great pot-hole 50 feet above the creek. Similar examples may be seen upon every river in the State.

4. Hence, wherever, upon all these rivers, we can find marks of drift agency low down on the rocks at gorges, we cannot suppose that rocky barriers closed those gorges during the period when the terraces were forming; and, therefore, we cannot call in their aid to explain the formation of the terraces and beaches.

5. Former beaches of the ocean may be found at all heights from the present level of the ocean to the height of 2500 feet above it, in New England. In Vermont they are found between the heights of 100 and 2200 feet.

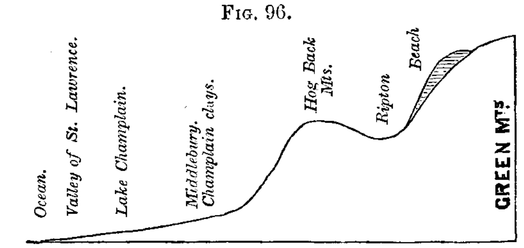
In the table of heights of beaches, etc., we have given the elevations of all the higher beaches in New England that we could find recorded, that it might be ascertained whether any considerable number of them might have been formed at the same time. The following cases are those that approximate most nearly to one another: In Thetford, 878 feet, and near the State line between Mass. and N. Y. on the western railroad, 890 feet. In North Ashfield, Mass., 1031 feet; Conway, Mass., 1033 feet, and in Newport, Vt., 1060 feet; East of Hudson River, near Albany, 1111 feet; Pelham, Mass., 1151 feet, and Shutesbury, Mass., 1167 feet. In North Ashfield, Mass., 1216 feet; Shutesbury, Mass., 1217 feet. In East Corinth, Vt., 1239 feet; Elmore and North Hardwick, Vt., on both sides of La Moille River, 1240 feet; Brownington, Vt., 1274 feet, and in North Norwich, Vt., 1287 feet. In North Ashfield, Mass., 1321 feet; North Norwich, Vt., 1337 feet, and on Copperas Hill, Strafford, Vt., 1340 feet. In Heath, Mass., 1561 feet; White Mt. Notch, N. H., 1569 feet, and on the summit level of the Western Railroad in Washington, Mass., on the continuation of the Green Mountains, southerly 1590 feet; On the summits of the Green Mountains in Peru, Mass., 2022 feet, and in Ripton, Vt., 2196 feet. The latter is the highest and one of the most perfect beaches measured in Vermont. None have been measured in New England above 2600 feet, and the highest may be a little doubtful. Other cases of similarly elevated beaches, particularly below a height of 800 feet above the ocean may be found in this table. Some of the above instances of agreement are 200 miles apart; and where several cases are adduced in different localities, the probability amounts to conviction that these different coast lines were formed at the same time and by the same ocean. And the Green Mountain range must have formed one long continuous shore.

If all the beaches in the country could be assigned to certain determinate levels, there would be some probability to the theory that the continent rose by paroxysms, and remained stationery during successive periods, while the modified drift was accumulating only at these determinate elevations. As the tops of the beaches have long been exposed to erosion, it might be difficult to determine their exact heights; but the few observations that have been recorded, would seem to indicate a series of beaches from the highest to the lowest, so complicated with one another in different parts of the country as to preclude the idea that they occur only at certain levels. These cases may be known by consulting the table of heights.

6. The waters that formed these beaches at the highest levels must have been the ocean. For most of the mountains are less than 2600 feet in height, and being therefore covered by the waters washing the beaches could not have served as barriers to retain inland lakes of fresh water. Every beach that has been observed in this State is either so high up as to overlook all hills between itself and the present ocean, or else, where geologists might conceive of a rocky barrier that would stop up the valley, and thereby form a lake upon whose shores beaches might form, drift striæ or other evidences of drift agency have been found at a lower level than the beaches; and as we have already shown that the beaches were formed subsequent to the drift, the conclusion is irresistible that no water except that of the ocean could have stood at these levels.

In Fig. 96 we give a section to show the relative positions of the highest beach measured in Vermont, on the west slope of the Green Mountains in Ripton and Hancock, and the surface of the country intervening between the beach and the ocean. It will be seen that the highest range between the beach and the ocean is nearly a thousand feet lower than the beach, and that no conceivable barrier could have existed between this bank of modified drift and the ocean.

Fig. 96.



Section from a beach at Ripton, Vt. to the ocean.

A simple syllogism will express the argument derived from this section for the former presence of the ocean at the height of 2500 feet above its present level. Banks of sand and gravel are found 2500 feet above the ocean. No conceivable local accumulation of waters could have formed them; therefore the ocean must have been the one grand cause for the whole.

Some consider no evidence of the presence of the ocean decisive, unless it have left marine remains, as it has done in the Champlain clays, and elsewhere. As these fossils are found so near to the Ripton beach, let us examine the connections of the two deposits.

1. Marine fossils have been found in the Champlain clays at the height of 540 feet, and clay, evidently continuous with the strata containing the relics, occurs at 756 feet. 2. The upper parts of the clays contain littoral fossils, and the lower parts contain pelagic fossils, among which are some foraminifera, recently discovered by Dr. Dawson of Montreal.—Hence, as these beds containing foraminifera (the same animals that were obtained by Lieut. Maury from the telegraphic plateau in the bottom of the Atlantic) rest upon the bowlder clay with no intervening deposits, we maintain that the continent was submerged in the drift and beach periods, and not elevated, as the advocates of the glacier theory suppose. For in that case the sinking of the continent, after its supposed elevation in the drift period, to the depth of 700 or 800 feet at the least estimate, to accommodate the foraminifera, would have left traces of its subsidence by the occurrence of alluvial deposits containing littoral remains between the drift accumulations and the foraminifera beds. These are not found; and it seems a plain inference from this absence of strata and fossils that the ocean at the close of the drift period was at this height over the continent without any intervening period. If this point be admitted, the submergence of the continent previously will readily follow.

The character of the Champlain clays and associated beds agrees with this statement. In the Champlain valley they are mostly clay, such deposits as are made only in deep and quiet waters. Their source was probably the streams descending from the Green Mountains, which, leaving the heavier gravel and sand at their mouths in this former ocean, would transport the fine particles of clay much farther into this body of water.—The current must have been southerly in the Champlain valley, as a submergence to the depth of less than 300 feet would connect the ocean at the mouths of the St. Lawrence and Hudson Rivers. The distribution of the deposits corresponds also with this view, for the coarser sand and gravel brought down by the Winooski and La Moille Rivers is retained in the form of terraces near their mouths, while the fine clay is mostly found south in the southern part of Chittenden and the whole of Addison County.

3. From the lowest locality of marine shells to the highest sea beach in the State (Ripton), there may be traced a continuous deposit of water-worn materials, generally of considerable thickness. The Ripton beach follows the west side of the Green Mountains southerly into Rutland County, and in Brandon, Pittsford, Rutland, etc., may be found at much lower levels, associated with moraine terraces. There are also what are marked beaches and sea bottoms on the Map,—continuous from the moraine terraces, and mostly composed of fine materials, to the terraces and Champlain clays on Otter Creek north of Brandon. The beaches and clays may have been formed at the same time, the one on the shores and the others at the bottom of the same ocean; and the great part of both in an arctic climate. Any one who will examine the union of the higher and lower deposits at these localities, can only be satisfied by ascribing to the same grand body of water, whatever that may be, the origin of both beaches and bottoms.

4. The respective characters of the sand and gravel of the higher deposits and the clays of the valleys may show why fossils are wanting in the upper beds. The compact clay permits no water to pass through it into the subjacent strata and gradually remove the carbonate of lime by solution; but the friable sand, containing also much feldspar, allows the free and rapid passage of meteoric water and of air through it. It would not be strange, therefore, that shells might have existed formerly in the gravel, but are now decomposed. There is a consideration, however, that leads us to suppose that shells never existed in these beaches, although the ocean was washing the shores. The ice which rendered the drift period too cold for life, had not yet disappeared. The icebergs, on account of their greater bulk beneath the surface of the water, could not approach very near the beaches, while they may still have floated in the Champlain and Connecticut valleys, and have produced the third and most recent sets of striæ, parallel with the courses of these valleys. Wherever they approached so near the beaches as to be stranded, materials were piled upon and about them, which, now that the ice is gone, appear as conical and tortuous hills, intermingled with similar depressions which have been described as moraine terraces. Hence we see that the ice might be so abundant, even in the beach period, as to form an arctic climate; so that very few, if any, forms of life existed.

It may be proper to state here, that no one of the Geological corps ever searched much for fossils in these beaches, in Vermont. And as they are generally upon high hills, very few excavations have ever been made in them, for any purpose. It would not be strange, therefore, if in future investigations such remains should be found, as they have already been in the drift upon Long Island and in Europe.

7. We ascribe to this period other forms of Surface Geology, particularly the higher Sea Bottoms, Submarine Ridges, Osars and Escars. These would be forming at the bottom of the ocean whose shores were the beaches already described. The beach period continued till terraces began to form,—generally till the continent was not as high as it is now by from 1000 or 1400 feet; or until terraces began to be produced instead of beaches. Still, some of the lower beaches would have been formed in the terrace period, as a few of the higher terraces would have been deposited in the latter part of the beach period. There was no definite line of demarkation between the two periods.

8. During the beach period, therefore, but a small portion of Vermont was elevated above the waters. The range of the Green Mountains, most of the north-east part of the State, and every foot of land that is elevated say 1200 feet above the ocean, then appeared like so many islands. As the elevation was gradual, every inch of surface was exposed to the washing of water, although beaches did not form everywhere, just as now on the sea coast there are alternations of rocks and sandy shores.

THE TERRACE PERIOD.

We have already stated the universal position of terraces—lying above all forms of drift—and therefore concluded that in general local barriers for the separate basins did not exist. We will now state a few principles respecting their position, modes of occurrence, etc.

1. The highest distinct terraces upon the different rivers, so far as we have measured them, are as follows: On Connecticut River, at Bellows Falls, 226 feet; at North Vernon, 237 feet; on Hoosac River, in Pownal, 307 feet; on the Battenkill, at west Arlington, 349 feet; on Winooski River, in Essex, from 240 to 260 feet above Lake Champlain; in Hinesburg, 300 feet; on La Moille River, in Georgia, 132 feet; in Johnson, 190 feet; in Hardwick, 380 feet; and on Lake Memphremagog, in Salem, 276 feet. Many others may be found in

the Table. The elevations were all taken above the bodies of water to which the terraces belonged, at the foot of the terraces. Though they are perhaps the highest terraces respectively upon their rivers, they are not necessarily the highest above the ocean. The highest recorded terrace above the ocean is the high terrace on the La Moille River,—380 feet above the river, and 1120 feet above the ocean. Higher terraces were seen even on the La Moille River, but were not measured.

2. The number, height and breadth of the river terraces, vary with the size of the river, the width of the valley, and the velocity of the current above the place where the deposits are made. Generally the number is greater upon small than large streams, while the height is less. This may be seen upon the various sections. Thus the terraces on the Connecticut are four or five usually; but on its tributaries, especially where they enter the Connecticut, the number rises sometimes as high as ten, as on Whetstone Brook and West River in Brattleboro, Saxton's River at Bellows Falls, and Williams River in Rockingham. In these cases the terraces on the tributaries are formed in the terraces of the principal stream; and though the former are more numerous, they rise no higher than the latter.

3. Terraces occur in basins both upon rivers and lakes. They may be conceived as having been formed in a series of ponds or lakes, connected together by a current, like the great inland lakes of North America. It is unnecessary to suppose that each of these basins was limited by rocky barriers, which were gradually worn away by the river itself. It has been shown that in most cases evidences of drift action may be seen near the bottom of these gorges, and therefore the rock must have been excavated at or before the drift period. We would not affirm that there are no cases in which the terraces were formed in consequence of a barrier thrust across the valley, either of rock or drift. We rather have affirmed, and described such cases; and think that in such cases the basins can be distinguished from the more usual forms by the equal height of the highest terraces upon the different sides of the valley.

Upon Connecticut River we have described twenty two basins, between its mouth and source: Upon Saxton's River, four; upon Williams River, three; upon Black River, six; upon Otta Quechee River, three or more; upon White River, at least nine; upon Passumpsic River, three or four; upon Otter Creek, probably five; upon Winooski River, five; upon La Moille River, five; and some others upon the smaller streams, or those that flow only a short distance in Vermont—as Hoosac River, Battenkill River, Pawlet River, etc.

4. The river terraces, excepting the delta terraces, rarely correspond in number or in height on opposite sides of the stream. The delta terraces wherever worn through by a stream, will of course have the same height on both sides of the river. When the valley is wide, and several terraces exist on opposite sides: by the eye alone, one is apt to imagine an exact correspondence in height. But the application of the level usually dissipates such an impression, as nearly all the sections of terraces given in the detailed descriptions will show. Were these sections carried across the rivers more frequently, it would have appeared that sometimes no terraces exist on one side, while there are many on the other; or that the number differs much on opposite sides.

5. River terraces usually slope towards the mouth of the stream by the same amount as the current descends, and sometimes more.

It is on the smaller and more rapid streams that we see this slope most conspicuously; indeed, on these it is so obvious that measurements were unnecessary. No measurements of this slope have been taken in Vermont.

6. Terraces are usually very high about gorges and obstructions in river courses. Such is the fact at Bellows Falls, on the Connecticut, and at Johnson on the La Moille River, besides many other examples. We have already shown that in consequence of the retardation of the current by a semi-obstruction, terrace materials would be deposited upon or near the obstruction. The same principle will apply to gorges, except that often the accumulations are found at the lower end of the gorges as well as the upper. They occur at the lower end of the gorges, because there the waters would spread out laterally and produce eddies or ponds, where detritus would accumulate.

7. The chief agent in the formation of terraces and beaches appears to have been water: for, 1st, the materials have been comminuted and rounded as no other agent but water can do; 2d, the materials have been sorted and arranged in different layers; 3d, the horizontal arrangement of the strata can be effected only by water. Having established this point, let us see in what condition the continent was, in this period, and for what reasons the detritus assumed the terrace form.

The continent is now supposed to be raised high enough to bring nearly all the surface above the water, which is now above the level of the highest terraces. The valleys are occupied as arms of the sea, in the forms of friths, estuaries and bays, or bodies of water entirely disconnected with the sea. In Connecticut River there would be a chain of lakes for the different basins. The rivers beginning to exist, produce a current in these estuaries towards the ocean. Their waters acting on the drift over which they run, would comminute and carry into the estuary the fine sediment, and thus form shoals or banks along their mouths. Meanwhile the ocean is sinking, and at length these banks will come to the surface, as small deltas to the rivers. The streams, too, will wear down their beds, as the estuary sinks, and hence they must cut passages through their deltas, and urge foward a new mass of sorted materials into the now diminished estuary. Thus another delta may be formed, and a third and fourth in process of time, even though the vertical movement be uniform. The delta terraces are formed everywhere, and in every period, essentially like the beaches, but more regular upon their tops, and perhaps of a different shape, as seen by protraction upon a map.

An example of the formation of deltas at the present day may be seen in Switzerland. In the canton of Unterwalden, the lake of Lungern has been artificially lowered within the last sixty years. Where the head of the lake formerly was, and into which a number of small streams formerly emptied, several deltas were laid bare by the draining off of the water, and they are cut through by the streams, which have worn deep chasms through the loose materials, and are still wearing them backwards towards the Alps.

8. Next let us consider how, in like circumstances, lateral terraces may have been formed. 1. The various streams might bring into the lake, or estuary, so much detritus that the whole valley below the surface of the water would be filled up. When the land had risen, the stream would cut a passage for itself through the deposit, leaving terraces

of the same height on both sides of the river. This process might be conceived to take place at different levels, and produce all the lateral terraces. This is a view suggested by Robert Chambers, and is adopted by many geologists. It is probable that many terraces were formed in this way, but it will be impossible to suppose all thus produced, as the number ought to correspond generally upon both sides, and their tops should always be at the same height upon both sides — which is not usually the case. Besides, the amount of detritus which would in this way be carried into the principal streams by their tributaries, or into the ocean, would be much greater than what is actually transported.

2. Instead of supposing the whole valley filled with detritus, let us imagine that a bank only is formed, fringing the valley below the water; either by the materials of the deltas of tributaries transported by the principal current and lodged near the shores; by the accumulation of sand, gravel etc., brought into the water on the shores, by the numberless little rivulets and streams that flow from springs perennially, or are brought into existence by every rain-storm; or by both these agencies united. If the level of the water continues to be the same for a long time, as when a barrier exists at the end of the basin, a lateral bank or terrace will form below the surface, which will be terraces, one on each side, whenever the barrier is removed. In this case also the terraces will be of the same height upon both sides of the valley, and not slope with the current, and there may be several terraces upon each side in this case, provided only that the barrier shall exist at several successive elevations.

Several terraces in Vermont may be referred to this origin. There are two kinds of them, those formed by the sudden bursting of the barrier, and those formed by the gradual removal of the barrier. Of the former class are the lateral terraces formed upon Runaway Pond in Glover, upon Lime Pond in Williamstown, and wherever any pond has suddenly left its bed in this way. Of the latter kind are probably the upper terraces at Proctorsville upon Black River. We do not think that any basin of terraces has been entirely formed in this way, because the terraces are of uneven height and have a lateral slope, the latter of which could never have been formed in a quiet pond or lake.

Another way in which lateral terraces are now forming, seems to have been the most common method of their production. It is thus described by Dr. Hitchcock. "Powerful freshets occur not unfrequently on all rivers; and in their swollen condition, and with increased velocity, they act powerfully upon their banks, especially if of alluvial materials. And if the course of the stream be tortuous, as is always the case, one bank will be acted upon more powerfully than the other. This action will produce a meadow on one side of the stream, but little raised, it may be, above the river in its ordinary state. Successive inundations will eat away the bank more and more, and thus widen the alluvial flat. The stream will thus be spread out over a wide surface during its floods, and of course its velocity will be lessened. This will cause a deposition of suspended matter to take place, whereby the meadows will increase in height. Meanwhile the stream will continue to wear its channel deeper, the supposition being that the drainage is still going on. At length the channel will become so deep, and the meadows so high, that even in freshets the waters will not spread over the meadows. They have now become a permanent terrace, bounded by the river on one side, and by a steep escarpment on the other, that leads to the higher terrace.

"As the river no longer rises over the meadows in time of floods, the process already described is repeated, and a third terrace is the result; and so a fourth, a fifth, etc., may be formed, if the river sink deep enough and time be given."

Add to this drifting action of the current, the deposits brought in as deltas of the various kinds of permanent and occasional tributaries, as previously explained, and we have the causes of nearly all the lateral terraces explained. See too how the latter view explains the slope and varying height and number. If the current of the stream had produced a terrace, it must slope with that current, through its whole extent, as the sand, etc., can never be brought above the level of the water, and must be brought near the surface. And in regard to the number and equality of the terraces on the two sides, we see that the energy of the current is principally devoted to one side of the stream; consequently but one terrace would form; and as the land was slowly rising when the stream began to deposit upon the opposite side, the top of the terrace would be lower than the one previously formed; though the difference would probably be but a few feet.

It is thus that we see the reason why a single high terrace may exist upon one side of a valley opposite to four, five or six. The current has always made its deposits, except in one instance, upon that side where the terraces are most abundant, and this change in number, height, &c., upon most streams, will vary with every prominent bend in the river.

We see also from this view why the terraces about gorges may be higher than those in the widest part of the basin. The contraction of the stream at the gorges would check the current, and thus cause more of the suspended matter to be deposited. Very probably it might so fill up the gorges, that as the continent rose it would require a great length of time to wear them down to their present depth.

9. Thus we have seen that the various forms of river terraces may be produced by the simple drainage of the country, as the surface emerged from the ocean. The methods by which the terraces were formed may sometimes have varied from those described, and wherever it seems necessary we should call in the aid of all the modes proposed. Nor is it necessary to suppose that there were pauses in this vertical movement. Such pauses may have existed, and in this way there may be certain determinate successive levels at which beaches and terraces are found — but to form the river terraces we need not call in their aid.

10. We can proceed further, and show that river terraces in general could not have been produced by pauses in the vertical movement of the land.

1. If thus produced, they ought to be the same in number and in height in the different basins of the same river; and if the whole continent was affected by the same paroxysm, all the terraces upon it ought to be subject to this law. Even though a slight difference in them be admitted, their number must correspond, since the water would sink equally in the different basins. But upon examining the different sections of terraces on previous pages, it will be seen that there is no such agreement. On the Connecticut four and five are common, but not unfrequently the number increases to six and sometimes seven, and almost every section presents a different series of heights. Upon the tributaries, we see the number frequently rise to ten. Which of these numbers shall be assumed as indicating the number of pauses in the vertical movement? If the smallest, then how are we to explain the excess? If the larger number, then why did not the waters leave traces of their influence alike numerous wherever they acted an equal length of time?

2. On this supposition, also, the terraces ought to agree in height, at least upon opposite sides of a valley. Circumstances, indeed, might erase all traces of their action in particular localities, but such great irregularity as exists in this respect, cannot thus be explained. We refer to every section that is measured to show this irregularity.

3. The difference in the number and height of the terraces on the principal stream and its tributaries at their debouchure, affords decisive proof that terraces were not the result of paroxysmal elevations. Here we find two sets of terraces formed in the same bank of detritus; one set, usually the smallest in number, on the main river; and the other set, formed by the erosion of the tributary through the first. For examples we refer to several of the sections. Upon Fig. 49, showing the number of terraces upon the Ashuelot River in Hinsdale, N. H., and upon the Connecticut at Vernon, we have five terraces on the former and three or four on the latter. Fig. 54 shows six terraces at the mouth of Saxton's River, while in Westminster (Fig. 53), a little to the south, there are only four.—In the north part of Vernon (Fig. 50), there are only four on the Connecticut; but on West River in Brattleboro, perhaps two miles north, we find nine, and on Whetstone Brook ten (Fig. 52, and Plate VII, Fig. 2.) And the latter rise no higher than the former.

Plate VII, Fig. 1, shows ten terraces upon Williams River, and five upon Connecticut River at its mouth, the tenth and fifth being of the same height. And as both of these sets are found in the same bank of sand and gravel, it is certain that if one set was produced by paroxysms, the other could not be; and if one set could be produced without paroxysms, the other might be also.

11. The same facts prove that these terraces were not produced by the bursting of barriers: for the results would have appeared in terraces of the same number and height upon the opposite sides of the stream, and the same facts that disprove the paroxysmal theory, disprove this theory also.

12. The lake terraces that occur in Vermont have the same origin as the lateral terraces of rivers. They may be explained either by the second or third methods, according as a current passes through the lake or not. And we have every reason to suppose that lake terraces all over the country are formed in the same way. We have described three pond terraces produced by the sudden drainage of Lime Pond in Williamstown. This case illustrates the formation of terraces by drainage.

The method in which moraine terraces have been produced has perhaps been sufficiently considered. Ice was called in with water. It was supposed that icebergs became stranded at the base and on the sides of hills, and that deposits were made around and upon them, and they would have been level-topped if the ice had remained; but in consequence of the melting of the ice they are now extremely irregular. No more satisfactory explanation of these phenomena has ever been given, and therefore we adopt this view,—certainly until a better one shall appear.

13. The facts and reasonings that have been presented, exhibit to us one simple, grand, and uninterrupted series of operations, by which all the changes in the superficial deposits since the drift, have been produced. We see the continent slowly emerging from the ocean; rivers commencing their wearing action on the islands; waves and oceanic currents meeting the detritus of rivers and comminuting, sorting, and arranging the same, in the

shape of beaches and terraces, while it may be that icebergs and glaciers modified the whole. It may be too that paroxysmal movements occasionally accelerated, retarded or modified, the effects. The period over which the uninterrupted operation of these agencies can be traced, may be regarded as the alluvial, and we can refer them back at least to the tertiary epoch.

THE HISTORIC PERIOD.

We are now brought to the period when the country had attained essentially its present altitude, the period of the later terraces and of man. All the agencies that produced drift, namely, icebergs, glaciers, land-slips and waves of translation, are still in operation in some parts of the world, and therefore *real drift* is still being produced. Ever since the tertiary period, these causes have been acting; but their intensity has varied in different ages.

The same is true of the agencies that have produced beaches, osars, escars, moraine terraces, marl beds, peat bogs, and deposits from springs, namely: the action of rivers and the ocean, combined with the secular elevation of continents. In other words, the agencies producing drift and modified drift have run parallel to each other from the very first. Hence they both are varieties of the same formation, extending from the close of the tertiary period to the present.

Man has existed upon the earth a comparatively short part of the Alluvial Period.—We have a few records of the commencement of the modified drift, in cases of old river beds upon a former continent, which will be described in another part of the Report.—The fossil Elephant from Mount Holly, and the Cetacean from Charlotte, and the littoral shells of the Champlain clays may have been coeval with man, though we have no reliable historic accounts of them, and probably they were vastly earlier.

[BY E. H., SENIOR.]

We introduce here, as perhaps the most appropriate place, an account of two quite anomalous phenomena which have fallen under our notice in the Modified Drift of Vermont. All geologists may not agree with our explanations: But we give the best that occur to us.

LAKE RAMPARTS.

A few years ago the newspapers contained an account of certain walls of rounded stones, lining the margin of some of the smaller lakes in Iowa, and which were supposed to be the work of man. One of our number suggested in the papers, without having seen them, that they were probably the work of ice; but we did not dream of finding the same phenomena in Vermont. Yet as we were exploring the shores of Willoughby Lake, we found the same thing on its northeast side, by the road to Brownington. For 40 or 50 rods the shore is fringed by a ridge, about a rod wide and five or six feet high, of coarse gravel and bowlders. The outer side is perpendicular, and the inside slopes gradually towards the water, having the shape of a rampart in a fort. Rev. S. R. Hall, who was with us, stated that he had seen the same phenomena on other small lakes or ponds, and on our Map of Surface Geology he has marked six other cases, viz., on the north side both of Great and Little Averill Pond; on the north shore of Island Pond; the east shore of a pond in Maidstone; the east shore of Memphremagog at its south end; and on the east, west and north shores of a pond in the south part of Franklin. Mr. Hall states that the rampart on some of these is 15 feet high.

These facts we believe are new to geology, with one exception perhaps, on Lake Onega in Russia,—and by what agency could these ramparts have been produced? for we are not inclined to refer them to human agency. But we think the ice of winter could have done the work. If the ponds, or some parts of them, are rather shallow, and the bottom covered by bowlders, the ice of winter would inclose the stones and the gravel of the bottom it may be, and from its well known property of expansion it would force the fragments from the central parts of the lake towards the shore. In one year the progress would be small; but in each succeeding winter the work would be resumed, until at length the fragments would be driven to the shore; and as the level of the lake, or at least of the ice, is usually higher in the winter than in the summer, they might be crowded a considerable distance beyond low water mark, and in the course of ages the accumulation might be large if the materials at the bottom of the pond were abundant. Formed in this manner, their outside would be as steep as rounded stones could be made to lie upon one another, and no wonder such walls should be regarded as of human production. We doubt not, now that a few cases have been pointed out, that many more will be found around the ponds and lakes of Vermont, as well as of other northern States.

DEPOSIT OF FROZEN GRAVEL WITH A FROZEN WELL IN BRANDON.

The presence of a mass of frozen gravel deep beneath the surface in Brandon, was first made known by digging a well through it in the autumn of 1858. The low temperature of the well the next summer called public attention to it. We visited it as soon as convenient, and up to the present time (October, 1860), some of us have been there repeatedly, and ascertained the facts respecting this well and the deposit, as they have transpired.

The frozen well is situated not far from a mile southwest of the village of Brandon, and from an eighth to a quarter of a mile east of Otter Creek. The surface is not raised very much above the river, and is undulating, a good deal sandy and gravelly, with one of the varieties of Eolian Limestone showing itself occasionally in bosses and low ridges, breaking through the gravel, and doubtless underlying the whole superficial deposit at no great depth. The gravel, also, rises into occasional knolls and ridges. In short, it is just such a region of sand and gravel as may be seen in many places along the western side of the Green Mountains; and, indeed, all over New England. It is what we call modified drift, and lies above genuine drift, having been the result of aqueous agency subsequent to the drift period. It belongs to the terrace period—probably to nearly the oldest terraces, which we have called Moraine Terraces. But greater detail will show the structure of the deposit at and around the well, where the frozen deposit was penetrated. Several wells have now been dug as deep as the frozen one in its immediate vicinity, but none of them have gone through to the subjacent rocks, so that the character of this rock can be of little consequence in our inquiries.

The frozen well was dug in this deposit in November, 1858. As stated to us by Mr. Twombley, the proprietor, and the man who aided him in digging it, for about 10 feet it passed through soil and gravel, then succeeded 4 feet mainly of clay. Below this lay a deposit from 12 to 15 feet thick, of frozen gravel, with quite large bowlders intermixed. Continuing the excavation 2 feet farther in the same materials, water was reached. The well was carried only a few feet deeper; its whole depth being not far from 35 feet. The frozen part which was passed through, appeared precisely like the same materials frozen at the surface in the winter.

Immediately west of the well rises a hill of gravel and sand, which is 30 feet above the well at the north end, and at its south end some 60 feet. This ridge A A (Fig. 97), is an eighth of a mile long, runs nearly north-east and southwest, curving towards the south at its southwestern extremity, and having a slope on its west side nearly as great as on its east side. Near its north end it is crossed by a road R R, which has been excavated to the depth of some 12 feet. Advancing southerly on this ridge we find it increasing in height (as represented on Fig. 98, on which the letters stand for the same things as on Fig. 97, and which is a vertical section of the ridge), till at length it stops suddenly, leaving the southern slope very steep. A little north of the road rises a ledge of limestone, B; another shows itself on the west side, some distance south of the road (B, Fig. 97.) These ledges doubtless had something to do with the formation of the ridge of gravel.

Fig. 97.

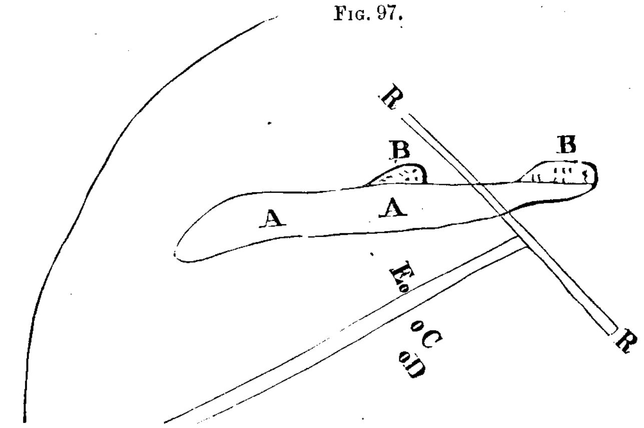
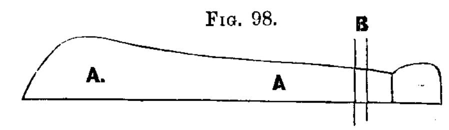
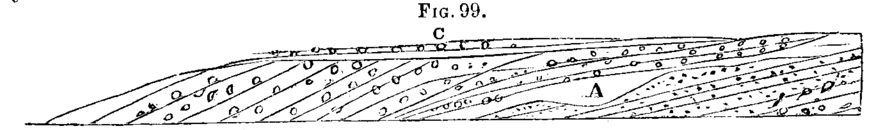


Fig. 98.



On the south side of the road where it crosses the ridge, a good section is exhibited of the materials of which the latter is composed. It is shown below on Fig. 99. It will be seen that gravel and coarse sand, with an irregular stratum, A, of light colored highly calcareous clay, varying in thickness from one foot to four feet, constitutes the deposit. At the top, the beds and laminæ, seen partly on their basset edges, however, seem nearly horizontal, C, but lower down they dip easterly, sometimes as much as 15° to 25—as much certainly as the slope of the hill. But at the foot of the hill doubtless the strata take a horizontal position, as the well-diggers thought them to lie, and as is usual in all similar cases. The gravel at the road cut is coarsest above the clay, the pebbles rarely being more than 3 or 4 inches in diameter, and in some layers being almost free of sand or loam, like the washed pebbles of a beach. Below the clay we find a considerable thickness of coarse sand, B, which also dips southeasterly. But at the lowest point, D, where the bank disappears beneath the road, it changes into gravel of the same character as above the clay.

Fig. 99.



The southeasterly dip of these beds of gravel, sand and clay, and the outcrop of limestone in two places on the northwest side, make it almost certain that this ridge of modified drift was formed by a current from the latter quarter, pushing the materials over the limestone ridge when the ocean stood above the spot. The pebbles and sand, sorted by the water, would of course take an inclined position on the slope of the limestone, but a horizontal one on the plain or valley. And we may regard the exhibition of the strata at the excavation in the road, as giving us a good idea of the deposit penetrated at the well.

We ought to add, that the soil in the valley in which the well is situated is clayey, with some pebbles intermixed. Probably gravel is reached very soon in descending, as those who dug the well spoke only of sand and gravel for 10 feet, when it becomes mostly clay for a few feet. The well was stoned up late in the Autumn of 1858, and during the winter, ice formed upon the water in one night, two inches thick. It continued to freeze till April; after which no ice was formed on the surface, but we can testify that as late as June 25th, the stones of the well, for four or five feet above the surface of the water, were mostly coated with ice; nay, it had not wholly disappeared July 14th. The temperature of the water was only one degree of Fahrenheit above the freezing point. The ice did, however, disappear in the autumn, but was formed again (how early we did not learn) in the winter, and so thick too that it was necessary to send some one into the well to break it. We visited the well August 18th, 1860, and found the temperature 42°. Yet only the week previous ice was seen upon the stones, and we were even told by one of the family, that a piece of ice had been drawn up the day before in the bucket.

It will be seen on a subsequent page, that we are much indebted to J. E. Higgins, Esq., of Brandon, for interesting statements concerning this well. The following facts are contained in a letter from him as late as January 9th, 1861. "In the old well," he says, referring to the first one dug, "there is now ice. Quite often during the month of December, the ice formed so thick during the night, as to cause Twombley to send his boy down to break it before they could have water. It froze over, the last of November, and ice has continued there since. I tried the water by a thermometer early in November and found it 38°."

These statements are quite important; for they show us that for three successive winters the ice has accumulated in this well, in apparently undiminished quantity; and thus is shown how groundless is the surmise of some, that this was a transient phenomenon—perhaps the mere freezing of the gravel at the time the well was dug—and that probably the statements of the well-diggers was greatly exaggerated. We know that some permanent source of cold exists in this well, and the facts concerning it already given and those yet to be presented are confirmed, and shown to be neither imagination nor exaggeration.

In 1858, the latter part of June, we took the temperature of a well or spring, only 4 or 5 feet deep, 100 rods southwesterly of the frozen one, and found it to be 51°. Another well, 12 feet to the water, and 60 or 70 rods northeast of the frozen one, was 45°. In the first case the frozen deposit seems not to have exerted any influence upon the spring; but the temperature of the other well is lower than springs usually are in the vicinity in summer.

On the 30th of August, 1859, the Boston Natural History Society, through the liberality of one of its members, commenced digging a well 70 feet southward of the frozen one, which was finished Sept. 20th. It was dug under the direction of J. E. Higgins, Esq., of Brandon, to whose kindness we are indebted for the following details:

"August 30th, 1859. Began sinking a shaft 70 feet southeast of the so called frozen well. First two feet, dark compact clay; then three feet of very fine sand; then, lower down, gravel and water-worn stones from the size of an egg to that of a barrel; chiefly limestone; after going three feet, *crystallized* limestone upon the cobble stones, which would look like frost, and this substance upon the lower side of the stone.

"At a depth of twelve feet, Sept. 4, found the temperature 50°, being 60° at the surface. Sept. 13th, at the depth of 20 feet, temperature 48°, and at the surface 54°; at the depth of 26 feet, no apparent change of temperature, gravel and cobble stones quite loose. Sept. 20th, reached 29 feet, and found water, the gravel and cobble stones having continued with little change till the last foot, in which was mingled some clay. Sunk the thermometer in the water, and it showed 46°, being 52° at the surface. A bucket of water drawn from the so called frozen well, showed 40°."

Another shaft was commenced soon after with the following results:

"Sept. 28th, 1859. Began a well 70 feet northwest of the frozen one; found gravel and cobble stones with some larger water-worn stones, which continued with little change till completed; depth 33 feet. The whole quite porous, and, as Twombley said, resembling that from the first (frozen) well.

"The temperature of the air at the surface and in the well grew colder, but no appearance of frost, the thermometer showing about 46°, till a depth of 20 feet had been reached. Oct. 19, the work having been interrupted some days, was again resumed: On the 20th of October, at the depth of 29 feet, found frozen gravel—a seeming crust two inches thick. Sept. 21st, depth 31 feet; earth frozen about eight inches: during both these days, digging no ice after going through the crust. On the morning of the 22d—depth 33 feet—found ice mingled with the gravel and frozen solid. Was hard to pick; at first supposed it like that the day before,—only a crust,—but the workmen say it continued solid during the day, and they worked into it only one foot, and all below seemed solid—could not drive an iron bar into it. Sent men down in the afternoon, who after digging from apparently solid materials, sent up gravel frozen hard, though the ice clearly showed itself and melted in the hand. This was at a depth of 34 feet from the surface. A thermometer in the well showed 38° and 52° at the surface. It had frozen slightly two nights before (at the surface), but water did not freeze in holes 18 inches deep."

Another well was dug about the same time by one of the inhabitants, 22 rods northeast of the frozen one, and close to the high ridge of gravel on the west. It was carried 40 feet, a good part of the distance through marl or clay, mixed sometimes with sand. Only a little water was found, which escaped when the gravel beneath the clay was reached.

Comparing the different excavations, the inference is that there is great irregularity as to thickness and position in the beds of clay and gravel, and as the former is an impervious and the latter a pervious stratum, it is not strange that water should occur at very different depths in the various wells. We venture to suggest, that had the first well dug by the Boston Natural History Society been carried deeper, it would have reached ice;

for there was a regular depression of temperature down to 46° just as in the second well, which was only 8° colder in the midst of the ice.

Subsequent to our presentation of this subject before the American Scientific Association, at Springfield, we received the following statements from Rev. J. W. Guernsey, of Greenland, in New Hampshire. They awaken the inquiry whether there may not be other spots, besides the frozen well, where a low temperature exists in the modified drift.

Greenland, N. H., Sept. 28, 1856.

Prof. Edward Hitchcock:

Dear Sir,—I am a native of Brandon, Vt., and have been very much interested in the accounts of the "frozen well," which I visited last summer. My home was in the north-east part of the town, about four miles from the well. In that vicinity are four springs—familiar to me in my childhood—whose waters were cold beyond any thing else of the kind I ever met. They are all within the area of a mile; all rise at the foot of gravel ridges, and are very copious. The first of these is by the side of the old stage road, leading from Brandon to Leicester, on the farm of Dea. Asa Burnell. The second is on the opposite side of the road, one-fourth of a mile south, just on the bank of Mill River, on the town farm, formerly known as the Goss Tavern. The third, about three-fourths of a mile to the northeast, forms the source of Spring Pond. The fourth, about one-half mile northwest of the third, is on the farm formerly owned by Harvey Guernsey, and sold by him to Hiram Alden who now lives near Dea. Burnell's, just by the first spring. I think these springs all rise in "Drift," and it occurred to me that they might be worthy of examination in connection with the well. The waters were so cold thirty-five years ago, that it was one of the tests of endurance among us boys, to see who would hold a finger in them the longest—a trial that none of us could endure more than a few seconds.

Of the four springs I think the third was the coldest, and the fourth the next to it. On visiting the neighborhood last summer, I found that the first spring had become as warm as such waters usually are. Mrs. Burnell, who has resided by it for fifty years, probably, remarked to me: "The spring is not what it used to be." I did not ascertain whether there has been any change in the temperature of the others or not.

Excuse the liberty I have taken in calling your attention to these springs. My only apology is the interest I have in the advancement of science.

Yours truly,

J. W. GUERNSEY.

Aug. 22, 1859, we visited the springs pointed out by Mr. Guernsey. The temperature of No. 2, several feet from where it issues from a sand hill, was 48°; that of the atmosphere 65°. No. 1, at Dea. Burnell's, was 53°. At Spring Pond the spring was dried up.

Mr. Joel W. Andrews published in the Albany Atlas and Argus, some observations which he made on the temperature of the water in lake Dunmore, about the first of September, 1859, showing a remarkable degree of cold. This lake lies about eight miles north of the frozen well. The average depth of the water was found to be between 50 and 60 feet. In one place at 75 feet in depth, Mr. A. found

Temperature of the air, ...	73°
do of the surface water, . .	70°
do of the bottom water, . .	41°
In another place, 65 feet deep, the water was	46°

We are indebted to David A. Wells, Esq. for referring us to these facts.

We have been led to inquire for cases elsewhere, analogous to that at Brandon, and have found a few, which we will briefly describe, because we think they cast some light upon the example in Vermont.

Rev. Ariel E. P. Perkins, of Ware, in Mass., dug a well in that place, in 1858, 35 feet deep through gravel and sand, which we know from personal recollection to be very much like that in which the Brandon frozen well occurs, except that there is less clay at Ware, and none of the pebbles are limestone. Last winter the water in Mr. Perkins' well froze over one night at least, though the ice was not much thicker than window glass. July 26th, 1859, the temperature of the water was 46°, which differs but little from the mean temperature of the region; and in the winter of 1859 it froze over again. Mr. Perkins' well is within his house and of course protected above, so that we must look to some other source for the freezing than cold air descending the well.

In the 36th volume, first series, of the American Journal of Science, p. 104, D. O. Macomber has described a frozen well 77 feet deep, in Owego, N. Y., which "for four or five months in the year is frozen so solid as to be entirely useless to the inhabitants." The sides of the well in winter are so coated with ice as to leave at the bottom a space of only a foot in diameter; and the ice on the surface of the water could not be broken by a heavy iron weight attached to a rope. It continues certainly as late as July, but disappears (as we understand the account) in the latter part of summer.

Another fact it may be important to state as to this well. "A lighted candle being let down, the flame became agitated and thrown in one direction at the depth of 30 feet, but was quite still and soon extinguished at the bottom."

This well "is excavated on a table land elevated about 30 feet above the bed of Susquehanna River, and distant from it three-fourths of a mile." In the excavation no rock or slate was thrown up. This statement makes it almost certain to our mind that the Owego well occurs in one of the sandy or gravelly terraces of the Susquehanna, and we have ascertained that such is the fact.

One other notice has been kindly sent to us by Dr. Samuel L. Dana, of Lowell, since we presented the subject to the American Scientific Association, and in consequence of it. "The frozen well discussion," says Dr. Dana, "has called to my recollection an account of a frozen well, which I saw some thirty six years ago in a Miscellaneous and Literary Journal published at Concord, N. H.

"I have hunted up the paper published in 1823, and signed Caleb Emery of Lyman, Grafton Co., N. H. He states that in 1816—that memorable cold summer—he visited in June a well in that town, which had become frozen over solid, eight feet from the surface of the ground, so that a hole had to be cut through the ice so as to get water. In July following he again visited this well; the water had fallen somewhat, but a mass of ice as large as a wash tub was still floating in it."

The cases which follow, although different in some respects from those above described, appear to belong to the same class of phenomena, and may furnish some hints towards a solution of the problem before us.

The 45th volume of the American Journal of Science, p. 78, contains an account of "Ice Mountain" in Virginia,—by C. B. Hayden,—where an enormous mass of debris rises several hundred feet against a rocky wall, and spreads as far horizontally; the fragments varying in size from a few inches to many feet in diameter. The interstices are occupied by ice, which remains, even only a few inches from the surface, through the summer.

Mr. Hayden explains this case on the principles of the common refrigerator, the debris forming the non-conducting sides. "The Ice Mountain, he says," is in fact a huge sandstone refrigerator, whose increased and unusual effects beyond those of the ordinary refrigerator, are due to the increased and unusual collection of poor conducting materials, which form its sides."

In the 46th volume of the same Journal, p. 331, Dr. S. Pearl Lathrop has described a similar Ice Mountain in Wallingford, Vt., where a mural front of quartz rock has a tal us of loose fragments covering an area at the base from 30 to 50 acres; and in a ravine opening to the southwest, where the fragments have been thrown, the ice occurs. It disappears from about first of July to September. Some of us have visited this spot, and presume Dr. Lathrop to be correct in accounting for the preservation of the ice on the theory suggested by Mr. Hayden; though, as we shall state further on, we should modify his theory considerably.

The "Ice Caverns" that have been described in Europe and Asia, present another phase of this subject deserving attention. Some of them were described long ago by Saussure and Pallas. In 1823 Prof. Pictet, of Geneva, presented in the Edinburgh Philosophical Journal (Vol. VIII, p. 1,) full details of the most interesting cases that occur in the Alps and the Jura. Two are noticed in each of these mountains. They are essentially alike, consisting of grottoes or caverns, one of which had on its bottom a surface of 3000 square feet of ice a foot thick, which was quarried in summer and constantly renewed.—From most of them there issued a strong current of cold air. This current was more powerful, and the refrigeration most active, in the hottest summers. Water was found in them all, and the air was quite damp and filled with vapor. Another cavern called "The Natural Glacier of the Rothorn in the Alps," is described by M. Dufour, in the same volume of the Ed. Philos. Journal, p. 290.

These caverns were so situated that snow could not have entered them to much extent during the winter. Prof. Pictet, as did Saussure before him, explains the refrigeration by supposing currents of air descending into the caverns in summer and escaping from the grottoes at the bottom. This current acquires in its descent the temperature of the surrounding rock, and is also greatly cooled if moisture cover the stones, by its evaporation. In winter the current of air is reversed, ascending through the uppermost opening. Then the evaporation is less than in summer, and consequently the cold produced is less.

To sustain these views, Prof. Pictet quotes many other facts. In Rome is a hill 200 to 300 feet high, called Monte Testaceo, composed almost wholly of broken urns and other earthen ware. Around the base several caves have been dug, from whose extremity chimneys rise to the surface. In the summer, when the thermometer above is 78°, there issues from these caverns currents of air at 44°. Many similar cases are quoted, partly natural and partly artificial, from Naples, St. Maria, near Terni, at Chiavena, on Lake Lugano, &c., all showing analogous phenomena.

More recently, Sir Roderick I. Murchison, in his Geology of Russia, (vol. I, p. 186), describes certain frozen caverns at Orenberg and Indersk on the Siberian side of the Ural Mountains, which are quite similar to those just described. They occur in hills of saliferous gypsum, which have openings at the top and the bottom, as in the Alps, and at Monte Testaceo. In spite of the ingenious theory of Sir John Herschell, of alternate descending waves of heat and cold, Sir Roderick regards the views of Prof. Pictet as the most probable, and quite sufficient to explain the Russian caverns. In these, the freezing for the most part takes place in the summer, and in winter the ice thaws; probably because the evaporation is so abundant and the air so dry in the summer, and so different in winter.

About two miles north of Brandon village is a cavern in a hill where ice is found most of the summer; but we cannot give details. A more striking example is an old iron mine at Port Henry on the west side of Lake Champlain. Ice is found here at a depth from 50 to 100 feet through the summer, and one of our number (C. H. H.) noticed a current of cold air issuing from the opening, as in the European caverns that have been described. The excavation is continued a considerable distance along the side of the valley, and one or two adits exist there, through which, and the perpendicular shaft where the ice is, the air current passes. This case of course is explained as the cold in the European caverns.

We have met with some facts respecting the frozen soil of Siberia, which seem to have some bearing upon the Brandon case. According to M. Erman, the ground in northern Siberia thaws during the summer from four feet eight inches, to six feet three inches.—A well at Yakootsk was dug or blasted in the frozen earth, to the depth of 42 feet, in fine sand and clay; and such was its temperature that Erman calculated that it would need to be carried to the depth of 630 feet before reaching the bottom of the frost. (*Lippincott's Gazetteer, Art. Yakootsk.*) M. Middendorf bored in Siberia to the depth of 70 feet, and "after passing through much frozen soil mixed with ice, he came down upon a solid mass of pure transparent ice, the thickness of which, after penetrating two or three yards, he did not ascertain." The same author says that in a shaft sunk in clay, sand and lignite, mixed with ice, the frozen crust was not passed through at the depth of 384 feet; though the temperature gradually rose from—1° at the surface to 26°.6 at the bottom.—M. Helmersen fixes the thickness of the frozen crust between 300 and 400 feet. In a pit he found a temperature of 21°.2 at 75 feet deep, and 31°.1 at 378 feet. (*De La Beche's Geological Observer, p.* 293.

Sir R. I. Murchison describes a shaft sunk 350 feet at Yakootsk which passed through 60 feet of alluvium, and the remaining distance through limestone and shale with some coal. The temperature in the shaft was in the summer 18°.5. (*Murchison's Russia, Vol.* I, p. 189.)

At Fort Simpson, on Mackenzie's River, in North America, in the same latitude as Yakootsk (62° N.), the thickness of the frozen crust was only 26 feet. (*Geological Observer*, p. 293.)

According to Sir R. I. Murchison it was the elevation of Siberia, at the close of the tertiary period, that changed its climate so that elephants, tigers and other tropical animals could no longer live there. But their bones, and in one or two instances their undecayed carcasses have been preserved in the frozen soil. We have some doubts whether such an elevation of the land, which appears to have been slow and not paroxysmal, can explain some of the facts respecting the frozen ground. At the depth of 70 feet there was found an alternation of layers of ice and frozen soil. How this ice could have been formed by the mere elevation of the land we do not see; but if that were slowly sinking and a deposit of soil was going on, such alternations with ice might occur, as they now do sometimes in arctic regions. Indeed we find it difficult to conceive how the soil and rocks even in a Siberian climate, as it now is, could have frozen to the enormous depth of nearly 400 feet, unless it was done while the strata were in a course of deposition near the surface, and were afterwards sunk to their present levels. The frozen animals by this view must have been encased near the close of this process; yet these are regarded as being as old at least as the drift period; so that we may be sure that this great mass of frozen soil is at least as old as the drift period.

In attempting to give some probable theory of the phenomena at Brandon, we shall approach the subject by a few preliminary positions.

1. We regard the cases at Ware and Owego as essentially like that at Brandon, and to be explained in the same manner.

2. The phenomena most probably have a connection with a gravelly and sandy soil, and hence we should make the character of such soil an element in our explanations.

3. As the frozen deposit is in such a soil, the idea is precluded that the congelation is the result of chemical re-agents. At Brandon, however, in describing the first excavation made by the Boston Natural History Society, Mr. Higgins describes an arrangement of the sand and pebbles which he calls "crystallized limestone upon the cobble stones, which looked like frost, and this substance upon the lower side of the stone." We think this was the effect of frost; for we have often seen it in the spring among pebbles and sand that had been frozen during the winter. The crystallization of the ice caused the finer materials to assume a correspondent form, and their semi-fluid condition, especially if in part comminuted limestone, would give room for enough play of chemical affinities to produce a slight cementation, but not enough to explain the refrigeration of the mass. These facts, however, do show the greater extent of the congealed state of the materials formerly than at present; for in this well, 29 feet deep, no frozen soil was found.

4. The fact that currents of air occur in probably all the frost caverns of the eastern and western continents as described above, awakens the presumption that they may exist, even if very feeble, in the porous soil of the frozen wells.

5. For similar reasons a still stronger presumption exists, that evaporation is perhaps the most efficient agent concerned in the preservation, if not the productioa, of the frozen masses in which the wells are situated.

6. The temperature in the wells is strongly affected by the temperature of the air at the surface. In winter the cold is much more intense than in summer.

The subject presents two leading inquiries: 1. When and by what agency was the congelation produced so deep beneath the surface? 2. By what means is the frost preserved from external and internal heat?

In reply to these questions we have two suggestions to make.

1. These frozen deposits may have been produced during the glacial period that accompanied the formation of drift, and continued far down into the subsequent epochs of modified drift.

That the drift period, and certainly the first part of the modified drift period, were characterized by intense cold,—such for instance as now exists in Greenland,—almost all geologists admit. The deposit at Brandon is probably about of the age of what we call moraine terraces, whose peculiarities we have supposed produced by stranded icebergs, and that the gravel and sand among these were doubtless frozen: indeed in some cases we think such ridges as that west of the well were formed by successive layers of ice and gravel. True, the period since that time we are disposed to reckon by piling tens of thousands of years upon one another. But if we can show how a frozen deposit, formed at any past period, might be indefinitely preserved, it is no matter how long ago it was first congealed.

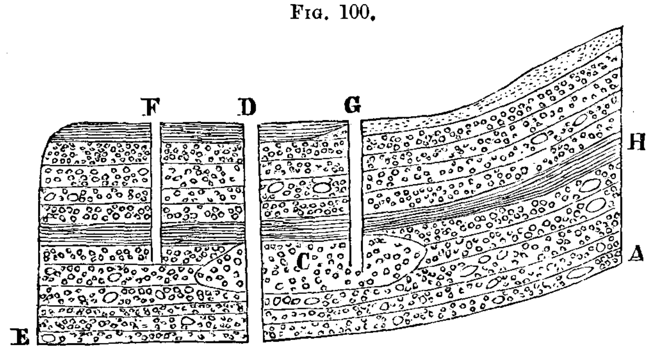
There are two sources of heat that would, without special conditions, melt a frozen deposit situated like that at Brandon: one, the heat of the sun penetrating downward, and the other, the internal heat of the earth permeating upwards. From the experiments of Prof. Forbes at Edinburg, it appears that external or solar heat penetrates only 49 feet in trap tufa, 62 feet in incoherent sand, and 91 feet in compact sandstone.

We should expect that pebbles and coarse sand would be poor conductors of heat, because the interstices are filled with air. The above statement shows that trap tufa, where the interstices are very small, is still poorer as a conductor; and we incline to believe that clay, especially the marly clay, such as that at Brandon, is as good to resist the passage of heat as tufa. One of us (A. D. Hager) made a few experiments on this point with this clay (which will be detailed in another place), that go to strengthen this opinion. The frequent preservation of ice among large loose blocks during the summer—as in the Ice Mountains in Virginia and Vermont, above described—might seem to show that the larger the fragments, and consequently the interstices, the greater the non-conducting power. But we do not believe that the non-conducting power of the fragments is the principal means, as it is in a refrigerator, of freezing the ice; but rather the evaporation, which would be greatest among large fragments.

All the excavations at Brandon show a mixture and irregular interstratification of marly clay and pebbles. The bands of clay doubtless lie both above and beneath the frozen mass, even though our section (Fig. 100) may not correctly represent the prolongation of the clay and gravel seen in the road cut, already described. But in all the excavations both gravel and clay occur: and how almost impervious to heat must such a coating, 20 feet thick, be! It would not, however, completely protect the subjacent mass from solar heat. But there is another agency still more powerful for this end, namely, evaporation, which we think has operated here, as we shall more fully describe further on; and we think that these two agencies, namely, non-conduction and evaporation, may have preserved this frozen deposit for a very long period, from exterior influences.

But how could the deposit have been protected against heat from beneath, which, though small in quantity, we have reason to believe is constantly working its way to the surface? The character of the strata, as they are exhibited at the section laid bare in the road (see Fig. 99), may furnish us with an answer to this question. Some of the layers there, consist of pebbles almost entirely separated from sand, or loam, such as we frequently see on the shores of rivers and the ocean. And the well-diggers testify that such beds were penetrated in making the excavation beneath the frost. Now such materials — and the same is true more or less of every deposit of loose materials coarser than impalpable powder — must contain a large amount of air in the interstices. The temperature of this air will be raised by the heat coming up from beneath, and being thus made lighter, it will escape into the atmosphere, and its place be supplied by that from abroad, which is denser and colder, and that by the same opening through which the heated air escapes, or through any other opening where the gravel comes to the surface. Thus the heated air would be carried off without scarcely coming in contact at all with the frozen mass. It would thus escape, even though the stratum of pebbles were horizontal, at any point where it comes to the surface. But it would facilitate the operation to have the bed inclined, as shown at A (Fig. 100), where C represents the frozen mass, H a layer of clay above it, D the well, and E A a stratum of clear pebbles. F and G show the wells dug by the Boston Society of Natural History.

Fig. 100.



Such an arrangement of the materials, similar to that at Brandon, reminds us of the construction of the most improved ice houses and refrigerators. One of our number (A. D. Hager), who first suggested this mode of explaining the preservation of the frozen deposit, has gone into greater detail on the subject, in a letter which will be found in the sequel.

If air can thus pass beneath such a deposit and convey away the heat that comes up from the interior, it would also exert another influence for the preservation of the ice, viz., by evaporation. The fragments would usually be moist, and often wet, and the inevitable effect of the contact of dry air would be evaporation, and the effect of this would be cold. Even though the motion of the air be very slow, these effects must take place, viz., evaporation and cold. If we exclude the idea of heat rising from the interior of the earth and thus causing the air to escape from the porous earth, while the external air of greater density takes its place, yet the changes of temperature in the external air must produce more or less of movement in the air that exists in the gravel and sand, admitting it to have a communication with that above the ground. These underground currents, whose existence is thus demonstrated, even though slight and slow, must produce evaporation and cold — how much, would depend on circumstances. But taking all the facts into account, some of us are disposed to impute a more powerful influence to evaporation, both in the production and preservation of subterranean cold, than to the non-conducting power of the materials.

Why might not the same effects be produced in a porous soil *above* a frozen mass?— That evaporation does take place to a considerable depth, even in common soil, is manifest during a drought; and in a gravelly soil it must occur still deeper and more abundant. Is it strange that such a cause, acting with the influence of a non-conducting deposit of clay, should effectually protect a frozen mass like that at Brandon, through thousands of years, ever since the modified drift period, from external heat?

But however we may explain it, the frozen earth of high northern localities has not been melted by internal heat since a period even anterior to that of drift, though the fact that below a certain point the heat increases even in the frozen mass, shows, in our opinion, that some effect comes from this source; yet so slight is it, that the soil remains frozen to this day to an immense depth. And we have the opinion of one of the most distinguished of the European geologists, Sir Henry de la Beche, that ice might have been preserved in such circumstances from the drift period to the present day. "Descended to a certain depth, beneath the surface," he says, "but not sufficient to bring it within the influence of the heat found to exist beneath certain depths in different parts of the globe, ice might remain there only to be thawed by a great increase in the temperature of the general climate, or by being again elevated, with a sufficient denudation of protecting detritus so that the heat of the atmosphere in summer would dissolve it and disclose any animal remains which may have been there imprisoned." *Geological Observer*, p. 293. Why may not the same reasoning be applied to Vermont as well as to Siberia?

The decided influence of the temperature of the atmosphere at the earth's surface upon frozen wells, may seem at first thought sufficient to account for their condition, without supposing a remnant of the ice of the drift period in their vicinity. The fact that the temperature of the wells is greatly affected by the external air is unquestioned; for the ice accumulates in them during the winter, and usually all thaws out before the close of summer. We have endeavored to show how the circulation of air through porous strata would produce such an effect. As winter approaches, the cold and heavy air would gradually work its way into the soil, and gradually lower the higher temperature beneath the surface. But would it ever be lowered below the freezing point, if there were not a cold mass below the surface with which it might come in contact? Then why are not all wells in porous soil converted into frozen ones? The fact that so few of them are such, gives plausibility to the idea that it needs a frozen nucleus to help on the process of freezing in winter, and retard melting in summer.

But, though we think this the most probable view of the subject, yet is it not possible to imagine a conjunction of circumstances in which frost may be produced deep in porous strata, and be gradually accumulated? Suppose layers of non-conducting materials to be underlaid by strata of coarser fragments, so situated at the extremities as to make the egress and ingress of air easy, either by simple difference of specific gravity, or aided perhaps by the pressure of wind. Suppose more or less of water to percolate through the gravel, and might not the evaporation by the air currents be sufficient in the winter to produce congelation deep beneath the surface, along the line of the currents? Might not a winter unusually long and cold produce so much of frost that the subsequent summer, especially if short and cold, would not melt the whole? And might not there happen a succession of such cold winters and summers, so as to accumulate a considerable quantity of frozen materials? We confess that when a series of warmer seasons should succeed, as they certainly would to balance the cold ones, we should expect the frost to disappear, unless in some way the openings of the pervious strata should be more or less closed. So that, while we suggest the possibility of such an origin to frozen buried masses, we cannot feel that the hypothesis has so much of plausibility in it as to be very probable. We have more confidence in the idea of the preservation of ice through the long interval since the drift period, and that this, in the manner that has been pointed out, gives rise to the yearly increase of the congelation, and retards the liquefaction in the summer.

From the difficulty with which air is made to pass through obstructed passages—even greater than that of water—we are aware that some doubt whether it passes at all through gravel and sand. But since the fragments of such materials must be irregular, and, therefore, have interstices between them, by what must the spaces be occupied if not by air? If by air, it must be subject to the influence of gravity and of expansion and contraction by heat and cold; and, therefore, have some motion; and if it can be made to change its place at all, why not so as to form more or less of a current, through wide spaces? We regret that we have not found time to perform any experiments on the transmission of air through pebbles and sand; for we have been unable, with a single exception, to find the record of any such experiments by others. The exception was an experiment by Saussure, upon the effect of evaporation by air passing through a glass tube only an inch in diameter, filled with fragments of wet stones. The air, when it entered from a bellows, was at 72°; but 66° when it emerged.

A fact was mentioned in describing the Owego frozen well which suggests the existence of subterranean currents of air. At the depth of thirty feet, not half the depth of the well, the flame of a candle was deflected horizontally. It was not affected lower down, and can, therefore, hardly have resulted from a descending current. Yet the effect upon the candle was greater than we should expect from a current issuing from the side of the well, though on a subject of which we know so little we can hardly tell what to expect.

The not unfrequent occurrence of living frogs deep in compact gravel beds, proves the existence, if not the motion, of air around them. For Dr. Buckland has shown that they cannot live long in cavities hermetically sealed.

An hypothesis to explain the frozen wells was advocated by Prof. Loomis, before the American Scientific Association in 1860, which imputes the congelation to the descent of cold air in the winter in consequence of its greater weight. The reason, according to him, why in the vast majority of instances wells and caverns (for we understood him to explain the lattter in the same way) do not freeze, is, that currents of water of rather high temperature flow through them and give off heat. Now, in the first place, there is no evidence that currents of water, with few exceptions, pass through wells, and not commonly through caverns, unless with extreme slowness. In general the water below the surface collects in the lowest places, and much more rarely than on the surface has any current except to pour into a well when first dug, till the whole is brought to a level.—2. Ice caverns are nearly as rare as ice wells; but by this hypothesis all of them not traversed by streams of water should be such. 3. Currents of cold air in summer in most cases issue *from*, instead of descending *into* freezing caverns; which shows that some other cause produces the frost. 4. The congelation in these caverns is often greatest in the

summer, the reverse of what it ought to be by this hypothesis. 5. But even if we admit that congelation may be produced in some open excavations by the descent of cold air, yet how could it produce such a thick mass of frozen earth as at Brandon, where from the character of the formation there can be no cavern, and where layers of clay must prevent the direct descent of air except in infinitesimal quantities. Though we believe that the external air does work its way horizontally through the gravel beds in this place, yet, as in the ice caverns, it is chiefly the evaporation thereby produced that causes the cold.

These objections seem to us insuperable against this hypothesis, nor would we with a dogmatic spirit urge our own views, but throw them out rather as suggestions for the consideration of scientific men. We have a suspicion that if careful and extended observations were made upon the temperature of springs and wells, evidence would be found in many places of the existence of a degree of cold in the earth explicable only by some local cause, such for instance as the existence of remnants of the congelation of the drift period. Is it not strange that this subject has received so little attention from geologists? Is it not deserving the attention of learned societies? we mean, that they should institute observations upon the temperature of springs, wells and caverns, and upon their geological situation; also upon the extent and character of subterranean air currents and subterranean evaporation. Not unfrequently such observations might not only eclaircise the phenomena of frozen wells and caverns, but afford important hints in the construction of ice houses and as to other means of obtaining a low temperature in hot weather.

We here insert the letter before alluded to, embracing the views of Mr. Hagar:

THE FROZEN WELL OF BRANDON.

Proctorsville, Vt., July 15, 1859.

PROF. HITCHCOCK:

My Dear Sir,— Agreeably to promise, I will give you my theory concerning the Frozen Well at Brandon. A few facts concerning it, its position and the surrounding objects, will first be given, as they form the basis upon which the theory is predicated.

The frozen well, which was dug last fall, is situated on the land of Andrew Trowmby, about three-fourths of a mile west of the village of Brandon, in a basin between two outcrops or spurs of limestone, that are about one-fourth of a mile apart, and running nearly parallel with each other in a northerly and southerly direction. Alternations of clay and gravel are common in the vicinity of the well. During the coldest weather last winter, ice formed upon the water in it, to the thickness of two inches, in a single night. The water, this summer, is not covered with ice, still, it indicates a temperature of only one degree above the freezing point, and yesterday I distinctly saw an incrustation of ice, several inches in thickness, upon the wall, just above the water.

North of the well, about ten rods, a spring issues from the surface of the ground, which is, in this place, as high as the top of the well. One hundred and twenty-five rods southwest, there is a well five feet deep, in a valley. The frozen well is thirty-four feet three inches deep, and has in it twenty-two inches of water, resting on a bed of clean pebbles. The spring and shallow well alluded to, have clay bottoms, and the water in them is not unusually cold. From information obtained of those who saw the well before it was *stoned up*, it appears that it is in what you denominate "modified drift," and in appearance resembled the banks of the gravel pit situated 130 paces northwest of it. As this gravel pit forms an important link in the chain of evidence favoring my theory, I will describe it quite minutely. It is by the side of the road leading from Brandon to Sudbury. For several years gravel has been taken from this place by the citizens of Brandon, for roads, &c. An excavation is made about ten rods long, and in some places fifteen feet deep. Upon the sides of this pit there are exhibited the edges of the strata of gravel, sand, clay, &c., that make up the terrace in which the pit is situated. The lowest stratum seen in the side of the gravel pit is composed of pebbles that are nearly free from dirt, and very closely resemble the water-washed pebbles found upon a sea beach. Upon this there rests a stratum of very stiff compact clay; and next above is found a bed of common gravel two feet thick. Above this is another bed of pebbles, succeeded by a thin stratum of clay, above which is found a stratum of sharp sand. Upon this rests the soil that forms the top of the terrace. These strata are not horizontal, but have a uniform dip of about 25° southeast, in the direction of the well.

Now my theory presupposes that these strata are continuous, and extend with others of like nature to the frozen well, and that the clean pebbles found in the bottom of the bank of the gravel pit may belong to the same bed that those do, found in the bottom of the frozen well. The pebbles are so free from dirt in the latter, that the water is never roiled by dropping the well bucket upon the bottom, even when the water is shallow. This pebbly bed was noticed by those who dug the well, and found to be easily penetrated. One of the workmen took an iron bar and ran it down into the pebbly mass, nearly its entire length, meeting with no more resistance than would be met in thrusting a bar into a pile of large marbles. It was immediately above this pebbly mass that the frozen earth was found by those who dug the well, and in it was found the water.

Now under ordinary circumstances ice will not form at great depths in the earth, and if placed there will soon melt. This is caused by the internal heat that finds access to objects in the earth's crust in various ways. It may be communicated to the objects through the conducting power of the materials that form the crust of the earth. Air and water are also important auxiliaries employed in the work of dispensing the pent up heat of the earth's center, to points at and near the surface.

That air permeates the earth at great depths, is evident, from the fact, that a wholesome atmosphere is usually found in deep, natural caverns, and it is not unfrequently the case that strong currents exist in them, and in some cases—as that of the "Blowing Cave" of Virginia—a current of air issues from the ground continually. Air is known to ascend from wells and deep fissures in the earth, in cold weather, from the fact that there is oftentimes found a thick coating of frost at their mouths, the result of the congelation of vapor brought up by the ascending currents of air. Unless the unphilosophical ground is taken that a *vacuum* is made, and continues to exist, at the starting point or source of these ascending currents, there must be descending ones to fill the space thus vacated. If, then, it be admitted that descending currents exist, they must, of necessity, be currents of *cold* air, for all understand full well the tendency of heated air to rise, and cold air to sink.

With the well-established facts before us, that oceanic currents exist, and not only exert an influence on the surrounding sea, but also upon the adjacent countries, by the equalization of temperature, we cannot well doubt the existence of running streams of water beneath the surface of the earth, and that they help to equalize the temperature of the earth's crust. We cannot believe that stagnant water exists beneath the earth, any more than it does upon it, or in the ocean. Indeed we know that streams of considerable size are found running, far beneath the surface, in limestone regions, where "sink holes" and subterranean caverns abound. The river Styx in Mammoth Cave, Kentucky, furnishes an example.

These deep seated streams often come to the surface, forming *cold springs* which have a uniform temperature the entire year, usually several degrees above the freezing point. The water *seems* very cold in the summer, but never is cold enough when it flows from the earth — even in mid winter — to freeze, hence the remark is often made that the water of such springs is "cold in the summer and warm in the winter."

Now if a frozen mass were placed in the earth and brought into contact with an ascending current of air having a temperature above the freezing point,—or with one of those subterranean currents of water,—it is evident that it would not long remain congealed.

The question now arises, why it was that such a congealed mass of earth was found in Brandon, at the time the frozen well was dug.

My opinion is, that the bad conducting property of the solids surrounding it, the absence of ascending currents of heated air, and of subterranean streams of water in this particular locality, favored such a

result; and that the bad conducting property of clay, as well as that of the porous gravel associated with it, taken in connection with the highly inclined porous strata, and the disposition of heated air to rise, and the cold air to remain below, contribute to produce in the earth, at this place, a *mammoth refrigerator*, embracing essentially the same principle as that involved in the justly celebrated refrigerator known as "Winship's Patent."

Clay is not only nearly impervious to air and water, but it is one of the worst conductors of heat in nature.* If we can rely upon the statements of those who dug out the frozen earth, it rested upon a stratum of clay that lay upon the bed of pebbles in which the water was found, for it was described as being a very sticky kind of hard pan.

This being the case, if the water contained in the pebbly mass had a temperature above the freezing point, the heat would be but imperfectly transmitted to the frost, through the clay, provided there was no other way for its escape. But we have seen that the stratum of clay that overlays the bed of pebbles in the side of the gravel pit was not horizontal, but inclined towards the well at an angle of 25°. Now if this dip was continued to the well, and existed there (which is highly probable), it will be seen that the ascending current of heated air, in the pebbly bed, would be checked upon meeting the overlying barrier of clay and be deflected out of its upward course. The tendency of heated air is to rise, hence it would continue its course along the under side of the clay, through the interstices in the bed of pebbles, till it found a place of escape at the surface, which in this case may have been at the gravel pit before named.

But from the fact that the valley, in which the frozen well is located, is surrounded on three sides with solid beds of limestone, and has upon the other side immense deposits of clay—sufficient to cut off all communication with subterranean streams of water as well as extensive currents of air—it will be seen that no internal heat could be communicated to that valley by either of these agencies.

The water in this basin is evidently cut off from all sources of supply, except such as falls upon the surface, and percolates through the soil into the reservoir which was reached in digging the frozen well; hence in a very dry time there may be a scarcity of water in it.

The spring alluded to, about ten rods north of the well, will be more sensibly affected by drouth than the well, for it is only the outlet from a comparatively small reservoir in a clay basin, and in a protracted dry time will fail to furnish any water.

Between the frozen earth found in digging the Brandon well, and the ice-beds that remain through the summer in some of the abandoned portions of the Cheever Iron Mine, near Port Henry, in New York, there seems to be a strong similarity of conditions. The ore veins in the latter, which dipped to the southeast, at an angle of 40° to 60°, were from ten to twenty feet in thickness, and have been removed—excepting portions that were left to support the overhanging rock—to the depth of one hundred and twenty-five feet or more, and six or eight rods in length upon the vein. While the air is permitted to circulate through the abandoned iron mine, and is impeded only by the occurrence of pillars that are left to support the roof of the mine, so it also circulates with comparative freedom along the interstices of the bed of pebbles that extends to the well, in a sloping direction from the gravel pit northwest of it. The dip of the bed of pebbles, and that of the orifice in the Cheever mine, are both from the northwest, so that the sun's rays, and the attendant heat, can never directly enter in there.

The water forming the ice-beds in the mine runs in from the surface, instead of being derived from springs that break in from depths below, and the same is evidently true of the water found in the basin around the frozen well.

But had running streams of water passed through the valley in which the frozen well is located, or along the bottom of that old iron mine, as is usual where water occurs in natural caverns, ice or frozen earth would never have been found in either place, during midsummer. But as these nether regulators of temperature are cut off, ice will continue to form in both during the freezing weather of winter, (the amount depending upon the intensity of the cold) and be slowly wasted away the following summer.

* To test the question whether clay was a poor conductor of heat or not, I took two basins of equal size, and in one put a coating of clay one half inch thick, into which I put water of a temperature of 52 deg. Farenheit. Into the other dish, which was clean, I put water of the same temperature, and subjected the two basins to equal amounts of heat; and in five minutes the water in the clean dish indicated a temperature of 70 deg. while that of the one coated with clay was raised only to 56 deg.