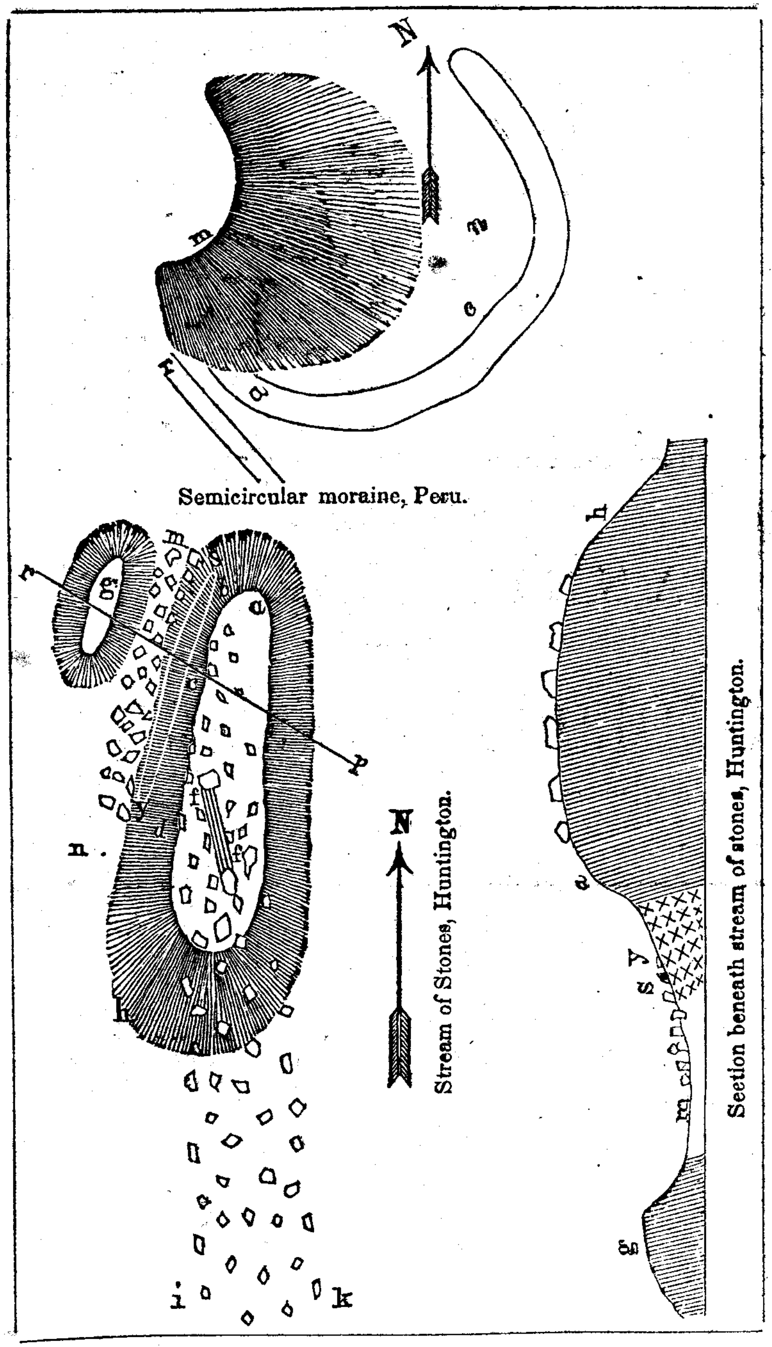
SECOND
ANNUAL REPORT
ON THE
GEOLOGY OF VERMONT.
1846.



Semicircular moraine, Peru.

Stream of Stones, Huntington.

Section beneath stream of stones, Huntington.

Elihu B. Taft

SECOND

ANNUAL REPORT

ON THE

GEOLOGY

OF THE

STATE OF VERMONT.

BY C. B. ADAMS,

State Geologist, Prof. Chem. and Nat. Hist. in Middlebury College, Corresp. member of the Bost. Soc. Nat. Hist., of the Entom. Soc. of Pa., member of the Assoc. Amer. Geologists, &c. &c.

BURLINGTON;

CHAUNCEY GOODRICH.

1846.

To His Excellency

William Slade, *Governor of Vermont:*

Sir,

I herewith submit the second report on the Geology of Vermont,

and have the honor to remain,

your Excellency's obedient servant,

C. B. Adams, *State Geologist.*

Middlebury, Oct. 1, 1846.

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ENGRAVINGS.

All the above engravings were executed on wood, by Mr. John G. Gay, of Whiting.

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* Original.

INDEX OF TOWNS AND COUNTIES.

ERRATA.

On page 64, line 12th from the bottom, for *cattle* in some copies read *battle*.
" " 84, the fourth word from the top, in the column of formations should be *pleiocene*.
On page 150, line 2d from the top, for *this town* read *Peacham*.
" " 152, line 19th from the top, for *Stawronies baileyi*, in some copies, read *Stauroneis Baileyi*.
On page 156, for *Fig*. 17, in some copies, read *Fig*. 35.

INTRODUCTION.

History of the Survey from October, 1845, *to October*, 1846.

The operations of the last winter were carried on at the depot of specimens in Middlebury, with the exception of the chemical analyses, which were performed in New Haven, Connecticut. The observations made during the previous season were arranged and written out for future use in the preparation of the Final Report. The data for several general sections across the southern half of the State were employed in the construction of these sections, which are so arranged as to shew the geographical relations of the several sections, and of their parts. The first essay towards a colored geological map of the State occupied some time: the State having been for the most part traversed by myself during the preceding summer, I was able, with important aid from the published sections and descriptions of parts of western Vermont by Professor Emmons, to construct a map, which requires only some few alterations and additions to be as correct as can be expected in the absence of such a basis as would require a topographical survey of the State.

A few days were devoted to the preparation of an outline of Elementary Geology, without which the description of the Geology of Vermont would be unintelligible to many who are not in possession of more extended elementary treatises. Most of this manuscript is published in this Report, and its preparation during the winter, without therefore encroaching on the season of field labor, accounts for what would otherwise be the disproportionate space allotted to it.

Much of the winter was occupied with the geological specimens collected during the previous season by myself and assistants. These were separated from the mineralogical specimens, arranged, trimmed, and, with the exception of the fossils of the Champlain rocks, assorted for distribution, ticketed, catalogued, examined and made the subject of copious notes, which will be used in the Final Report. These specimens were arranged in the proper order of the subjects which they illustrate. The labor of trimming specimens devolved upon myself, and as unfortunately those which were collected by my assistants had been taken without sufficient regard to their size, form, freshness, &c. much time was consumed in the attempt to reduce them to a proper condition, and about one thousand which were too small were rejected; a loss which falls very disproportionately on the duplicate suites designed for the literary and medical institutions, and which it is necessary thus to explain, to account in part for the greater number of specimens which will be found in the collection designed for the State.

On each specimen has been put, with poisoned tragacanth paste, a margined ticket with figures printed with pica Egyptian type. The corresponding specimens in the several suites, of course, received the same number. The manuscript catalogue of the specimens, amounting in the State collection to 935, was nearly completed when an uncommonly early season called to field labor. The specimens of the State collection are arranged on shelves in an apartment of the Geological depot, for consultation by the Principal during the progress and completion of the survey. Since it is in some cases not practicable to obtain the requisite number of specimens of a given kind for all the suites, the State collection will therefore be the only perfect suite. The remaining specimens have been put each in a wrapper, on the outside of which the number of the specimen is written in duplicate.

About one hundred figures, in part for the present, but mostly for the Final Report, were drawn. For most of these, being a suite of figures of the more important varieties of clay stones from a locality in Pittsford, the survey is indebted to Miss Adeline P. Thompson, the daughter of my assistant.

Having arranged a plan of the field operations for the present summer, this labor was commenced by me early in the season. During the unsettled weather of spring, short excursions were made into various parts of Addison and of the adjacent counties, chiefly with reference to the Champlain and Pleistocene formations and the Taconic rocks.

A visit was next made to Orange County, where the operations of the survey were greatly facilitated by the gratuitous coöperation of Dr. S. W. Thayer, Jr. The geology of the southern half of this county was examined in company with Dr. Thayer, and collections of minerals were made at several localities.

In the next tour through portions of Rutland, Windsor, and Windham counties, I was honored with the presence and coöperation of Your Excellency. The results both of economical and of scientific interest were too various to be mentioned here.

The next excursion was made through Washington, Caledonia and the north part of Orleans counties, and some important results obtained for the Geological map, and in the first named county the most remarkable examples of striated and polished rocks were discovered. A visit was also made to the White Mountains in New Hampshire for the purpose of finding the evidences of Drift agency at an elevation greater than exists in Vermont, and in which we succeeded. During this excursion I was accompanied by Mr. Thompson; and by Rev. Ebenezer Burgess of Ahmednugger, India, who assisted in our labors gratuitously.

A tour was then made through the north part of Chittenden, and through Franklin, Lamoille, and Orleans counties, with numerous and highly interesting results. In the two former counties were found abundantly extraordinary exhibitions of Drift furrows and polished rocks. In the vicinity of Burlington were found interesting Pleistocene deposits with abundance of marine shells of existing species, among which was one, Lucina flexuosa, which had not hitherto been known to exist in a fossil state. In this vicinity I was accompanied by Mr. Thompson. In Franklin county His Honor Lieutenant Governor Eaton accompanied me in various parts of Enosburgh and in part of Bakersfield. In Lamoille county the valley of the Lamoille River was found to exhibit the same extraordinary deflection eastward of the Drift current, which was first noticed by Dr. Jackson in the valley of the Winooski. Mr. Hall accompanied me through various parts of Orleans county and rendered efficient aid in the exploration of the rocks and in the collection of minerals.

Subsequently to this tour, some short excursions have been made in Rutland and Addison counties with various but interesting results. These have been continued more or less frequently, up to the time of the printing of this report, and, with the other numerous miscellaneous duties of the Survey, will, it is hoped, be a sufficient apology for the obvious marks of haste on these pages.

It is obviously unnecessary to describe the details of the operations of each successive day in the order of their occurrence, and the description of them in a systematic arrangement must be reserved for the Final Report. Yet as some curiosity exists in reference to the manner of proceeding, I will narrate in detail here, as a specimen of a day's work, the history of one day which was of rather more than common interest, during which I was assisted by Mr. Hall.

Aug. 11. Finding the air remarkably clear, and the weather promising favorably, we resolved to take advantage of it for our proposed ascent of Jay Peak, and accordingly started from Lowell at half past four o'clock A. M. We passed by the serpentine ranges of this town, and rode eight miles to South Troy 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. The great extent of this deposit was subsequently found to have been due in part to the number of streams, which converge into this valley from the head waters of the Missisco, acting in the older Pleistocene period on the then recent and fresh materials of the Drift.

Here we found that the thermometer attached to the barometer had been broken, but fortunately the barometer itself was sound. At this valley, in the lower story of Mr. Johnson's Hotel, at 7½ A. M., the barometer stood at 29.26 inches; and the detached thermometer hanging near it for half an hour indicated a temperature of 70° Fahr. which was probably not far from the temperature of the instrument; the height above Lake Champlain is therefore about 650 feet.

Having made our arrangements, we started for the ascent, accompanied by Mr. Johnson, Major Bates, Elder Downs, and Mr. Nathaniel B. Norris. A ride of a few miles brought us into Jay about 2½ miles from the east and two miles from the south line of the town, where we left our horses and proceeded on foot, through an unbroken forest, to the Peak, in a south west direction. About four miles of the route was a moderate ascent, and was followed by two miles of a steeper but not very rough surface, when we arrived at the naked peak. The route thus far was indicated by "spotted trees," which had been marked from time to time, and many of them during the previous summer, when the mountain was frequently ascended by a party engaged in making night signals from the summit for the surveyors of the United States and Canada boundary line, and who had a camp on the mountain. Except for the obstruction of fallen trees and the straggling moose bushes, the ascent is quite easy as compared with many of the mountains of Vermont, and if a good bridle path were constructed, which would require scarcely any thing more than the removal of the fallen trees, the ascent would be as easy as to the same height on the White Mountains. Occasional fragments of coarse talcose slate were seen, but the rocks in place were mostly concealed.

We ascended the steep rocky apex for about one-sixth of a mile on the west side, which is covered with debris of the coarse talcose slate in angular blocks mostly from one to four feet in diameter. The north side is a sheer precipice of 500 or 600 feet. The summit we found to be of the same rock, the talc in rather large proportion, with numerous small irregular masses of pure chlorite, and an irregular vein of white quartz. The rock is highly charged with very minute crystals of magnetic iron ore, so

as powerfully to affect the magnet, especially the small agate poised needle of my pocket compass, which in different positions pointed in exactly opposite directions, indicating strong polarity in given portions of the rock. The abundantly disseminated crystals however seem to be a sufficient cause, and the presence of any workable mass of ore is not by any means certainly to be inferred. By repeated observations with two compasses elevated a few feet above the rocks, we probably approached near to accuracy. The direction of the strata is about north 10° east, and the dip from 80° west to perpendicular. Mr. Hall collected a variety of specimens, which, although less than our standard size, proved in the course of the six miles descent to be sufficiently large.

With the exceptions of an area of a few yards at the west end of the summit, beginning at an elevation only eight feet lower than the highest point, the rocks were mostly covered with *drift furrows*, many of which were very distinct, with a direction of north 40° west. The drift current here was deflected to the east of its usual course by the deep valley of the Missisco east of the Green Mountains, which are prolonged to the south at an elevation but slightly less than that of the peak, and were therefore an obstacle to the usual course of the drift. The furrowed surfaces are somewhat rounded, but owing to the disintegration of the rock, the finer scratches and smoothness of the surface, which probably existed at the close of the drift period, have disappeared. The masses of angular debris, over which we had ascended, sufficiently indicated the powerful effects of the destructive agencies of frost and rain since the time of the drift current, which, being powerful enough to furrow the rocks, must have then removed the preëxisting loose fragments.

The barometer was taken up and down the mountain with great care by Mr. Norris, who was also of great service in readily detecting the "spotted trees," where they were infrequent. When first set up, at 1 P. M. it stood at 26.113 inches and the detached thermometer at 62° Fahr. The instruments were hung together in the shade for 1¼ hours, when at 2¼ P. M. the barometer stood at 26.1 inch, and the thermometer at 60½° Fahrenheit, both being probably at very nearly the same temperature. Subsequently calculating the results, with the observations on Mr. Thompson's wheel barometer at 1 P. M. of the same day, we find the elevation to be 3918½ feet above Lake Champlain; while with an observation with Mr. Thompson's Bunten's barometer at 1¼ P. M. of the same day at the level of the Lake in Shelburne, the result is 3938½ feet, giving as a mean 3928½ feet above the Lake or 4020 to 4025 above the ocean.

The scenery we shall not attempt to describe. The scattered mountains of Canada on the north with the intervening broad lands, Lake Champlain mapped out on the west with its islands and bays, and the White Mountains of New Hampshire in the extreme east, were the principal objects.

A little bed of sphagnous moss, a few feet below the summit, with its matted roots decayed to the depth of a foot, was an object of some interest at this elevation, and in a region where sphagnous swamps are scarcely known.

Both on our ascent and descent we stopped at a small brook, two miles below the summit, which we called 'Cold Brook,' the water having a temperature of 43½° Fahr., not far from the mean annual temperature of this region.

We reached the foot of the mountain about sunset and proceeded towards North Troy. When about three-fourths of a mile west of the middle of the east line of Jay, we came to a ledge of serpentine, a continuation of the Westfield range and west range of Lowell. A vein of supposed magnetic iron ore was pointed out to us, which however had but little influence on the magnet. Making the necessary observations, we collected specimens for examination by daylight the next morning, when we found it to be chromic iron, of great value, which will be described under its appropriate head.

The chemical analyses were made by Mr. Denison Olmsted, Jr. in the laboratory of Yale College. A melancholy interest is attached to his report, from the fact that it was his last, although almost his first, public labor of science. A rapid consumption marked him for a victim, while completing this task, and when arrangements had already been made, by which his high attainments in mineralogy were to be made available in the field labor of this survey. His promptness and fidelity, his skill and rapid acquisitions in science had raised the highest hopes of the value of his services to the survey. These hopes have been disappointed by the decease of Mr. Olmsted on the 15th of August last.*

The tabular results of the analyses are dispersed through the report under the several subjects to which they belong, and the brief description of the general methods of analysis will be found in the appendix, C.

The Rev. Zadock Thompson has been employed in field labor, mostly in Chittenden County, with very interesting results, especially in the discovery of numerous trap dykes, without however a single example of an overlying mass of trap. Mr. T. has also rendered very valuable aid in the preparation of town maps and in the collection of the various scattered observations on the height

*See Appendix, Article B.

of different points throughout the State, a work of the utmost importance for the Geology of the Pleistocene period.

The Rev. S. R. Hall has been chiefly engaged in the Agricultural department of the survey, and the plan as well as the results of his labors will be found in their place in the part of this report, which treats of Economical Geology. The great value of these results cannot but interest deeply all who are concerned in the prosperity of this State.

Both of these gentlemen have not only labored with great industry and efficiency during the time for which they have received compensation, but have also, throughout the year, gratuitously devoted much time to the furtherance of its objects.

Various assistance has been rendered in the depot of specimens by Dr. S. P. Lathrop, by several members of the senior class in Middlebury College, and by Mr. A. R. Holmes, of New Bedford, Mass. Much credit is due especially to Mr. H. for the neatness and precision with which the numerous details of labor on the specimens were performed.

It is with much satisfaction that I repeat our acknowledgments to the citizens of the State, whom we have met in the field operations, both for their hospitalities and for their zealous coöperation. It would be agreeable to us to enumerate the many favors of this kind, but they are far too numerous to be introduced here. We have also much satisfaction in recording our experience of the quiet and orderly public houses, with a single exception, which we have every where found.

The very general desire of personally attending and aiding in the field operations, on the part of the citizens of the several towns, has been often coupled with an apparently confident expectation that one or two weeks at least would be devoted to the examination of each town. As it would be extremely unreasonable for us to expect to find in the community generally, a practical knowledge of the manner of conducting geological explorations, we must be allowed frankly to say that we have usually found any thing but correct views on this subject. Few are aware of the numerous and important inferences which may be made by a single and even rapid ride across a town, which often gives a practical geologist a knowledge of the structure of the whole region and of its general features, and thus furnishes the data for inferences of great economical importance. We have not found it generally considered that *there is a structure* more or less regular to particular regions, and that consequently it is no more necessary to examine every acre or even *every* square mile for the principal results, than it is for a mechanic to examine every square inch of a piece of timber in order to ascertain what it is.

Nor will any deny the propriety of our having a plan with somewhat fixed and definite objects in view, which however is inconsistent with the common expectation that we are, to transpose the language of my esteemed and revered instructor,* to follow the leadings of the inhabitants rather than of the rocks. Perhaps it is not improper to say that we often know more of the rocks in a town that we have never seen, than do any of its inhabitants, which may at first seem to be a singular or even uncourteous assertion, than which nothing is farther from our intention; for it is not more remarkable, than that a mechanic should know more of the mode of constructing a house which he has not entered, than does even its owner and occupant. We are encouraged to offer these explanations by the general facility with which we have found them apprehended and appreciated.

On the other hand the limit of the survey, which is fixed in the Bill making provision for it, renders it necessary to make the examination with much less minuteness of detail than would be desirable, and although it would not be useful to devote a week or more to *every* town, there are many whose mineralogy and geology merit this amount of attention.

Not far from 7000 specimens have been obtained during the present summer, of which I have collected in person about 5000. A large majority of these, like those of last year, are either geological specimens or specimens of the useful minerals. It had been my design to employ Mr. Olmsted in the collection of the various minerals of scientific interest for which Vermont has been somewhat celebrated. The melancholy disappointment in this plan has rendered it expedient to give some time in person to this object, and some localities of much interest have been visited, and full suites of specimens from them have been selected. But the almost exclusive devotion, by one individual, of at least one season to this object, is indispensable to do justice to it.

The importance of collecting and depositing in suitable places numerous specimens illustrative of the geology and mineralogy of the State, which shall be described in the Final Report, is probably appreciated by most of the community. As vouchers for the statements to be made, or as materials for correcting them, as means of comparison with minerals which may be found by persons not very familiar with their character, and especially as a help to any who may be commencing the study of our Geology,—for these and other purposes they are indispensable. I have, therefore, zealously endeavored to carry out the views of your Excellency on this subject, notwithstanding the great amount of manual labor which necessary results.

* See letter of Pres. Hitchcock in the First Report, page 67. We may add, too, that since our work is chiefly with the rocks and minerals, and not in indulging ourselves in social intercourse, those persons, whom we have not had the pleasure of seeing, are not *therefore* to infer that their town has been neglected.

The plan for the ensuing year may be stated in part and in general terms, although the difficulty of providing for all the chemical analyses, and the securing an assistant qualified to collect fine specimens of the simple minerals, with the amount of funds at my command, renders it impracticable now to form a plan with confidence as to all its parts. The fossils and the simple minerals collected last year, and all the specimens collected this year, are, so far as my time and the amount of assistance will permit, to receive the same attention which was given to the geological specimens last winter.

Should it be thought desirable, a large portion of the specimens with catalogues may be made ready for distribution to the several institutions before the commencement of another season of field labor. Whenever the distribution shall take place, the principles on which it shall have been made will be publicly announced.

The preparation of sections and of other figures, and the writing out of many of the results of the field labor will again require much attention. The analysis of minerals will also be carried on.

During the next summer, the collection of minerals throughout the State, the geology of much of the north east and of the south west extremes of the State, the additional examination of the geology of many districts, which have been partly examined, and the continuation of the agricultural department will occupy all the force that can be brought into the field.

For the analysis of minerals I have appointed as chemist to the survey, Mr. T. S. Hunt of New Haven, Connecticut, who is amply qualified to fill the place of his lamented predecessor, and who performed a part of the analyses herewith reported under direction of Mr. Olmsted, during the illness of the latter. The analyses will be performed, as before, in the laboratory of Professor B. Silliman, Jr.

The analyses of soils is an important object contemplated in the Bill providing for the survey; but in order that such analyses should be of any service, they will require, even if the time and skill of a professed chemist could be obtained gratuitously, an expense, which cannot be met with the present funds of the survey. We shall, therefore, offer further remarks on this subject under the head of 'Expenses of the Survey,' in the Appendix.

It seems necessary to remark on the expectation, which has been entertained of these annual reports, that, although finished on the first day of October, as required by law, they will contain all the results, and thus afford a means of judging what progress has been made, *up to that time*. That those, who are not practically acquainted with the operations of a geological survey, should look for its returns simultaneously with the autumnal harvest, may not be surprising. Yet we think such expectations will be waived, when it is considered that nearly all the scientific results are reserved for the Final Report, and that no small part of the results in economical geology are made out long subsequently to the publication of the Report, after receiving the details reported by the assistants, and obtaining the results of the chemical analyses. A full report of the operations of one season could not be in readiness before the following spring. Nor would it be expedient, on the score of economy, to publish a full report every year, when the Final Report must necessarily include all the details of the survey. It should be remembered also that the preparation of a full and elaborate Report, if possible to be prepared before October first, would seriously cut short the labors in the field. Yet, as the servant of the people, we have endeavored, as far as practicable, to meet this expectation, and have prepared a report somewhat more full than otherwise might have been thought necessary.

PART I.

ELEMENTARY GEOLOGY.

Design of this Part.

Since the application of geology to the economical objects of the survey would not have been intelligible without an introductory sketch of some of the general features of the science, a few preliminary considerations were presented in the first Report, for the benefit of those whose occupations do not permit them to study extended treatises of general geology. As this report is not restricted to objects of economical importance, it becomes necessary to present here a more particular view of some of the facts and theories on geology, in which the attention will be chiefly directed to the present and later periods in the geological history of the earth, reserving the particular consideration of the more remote periods for some future occasion.

An important object of this survey is to raise up geological observers, who shall take up the work where the government may leave it, and prolong it indefinitely. With this object also in view, we submit the following hastily prepared introduction to the *principles* of the science. For an observer to neglect these would be empiricism, and no one is prepared to make valuable observations without some elementary knowledge. Yet while the most extensive and profound acquisition in any department of physics may find ample scope in this noble and comprehensive science, any intelligent mind, with some rudiments of knowledge and a due measure of perseverance, may enter these broad fields and aid in their cultivation. One of the most valuable works, on the geology of Scotland has been recently written by a self-taught stone-cutter, whose volume* has received the highest encomiums from the veterans in British geology.

The scientific reader, if perchance there should be such, will allow me to remind him, that while it is hoped that the results of

* "New Walks in an old Field," by Mr. Hugh Miller.

the survey may not be without interest to him, these reports are written primarily for the information of those, at whose expense the survey is conducted. Although the geological reader will find many familiar facts, which he will pass over, the writer considers himself justified, by the extraordinary interest manifested by *the people* of Vermont in the Geological Survey, in presenting a report, whose object is not only to add to the pecuniary resources of the State, but to that intelligence for which it is distinguished.

CHAPTER I.

GEOLOGICAL AGENCIES.

Presuming that the first report is in the hands of my readers, I proceed from those preliminary remarks (pp. 9–15), to the consideration of *existing agencies*, which are producing geological changes on the surface of the earth. With a constitutional belief in the constancy of the laws of nature, we look to the operations now in progress, not only on account of their intrinsic interest, but because they alone can enable us to understand the history of the past. If we shall find strata now in the process of accumulation beneath the waters, burying within them the present races of animals and plants, marine, fluviatile, or terrestrial, the species of hot or those of cold climates, according to the situation in which these deposites are forming, and if we see unstratified rocks resulting from eruptions of lava, we shall be better able to comprehend the origin of ancient deposits with their imbedded relics of species which have long been extinct, and of those enormous masses of unstratified crystalline rocks, which exist where the volcanic fires have long since gone out.

Intensity of Geological Agencies.

Some very able geologists are of the opinion that the course of nature has been, through all the geological epochs, the same as at present, not only in the nature of the agencies of change, but also in the degree of intensity with which they have acted; that volcanic forces have never been more violent than they are now; and that there have been no other changes of climate than those which are consequent on changes in the relative distribution of land and water. Many others suppose that volcanic convulsions of the earth's crust have been more violent and on a larger scale than at present; and that the earth's surface was once intensely heated by the internal fires, so as to support the

dense tropical vegetation and the tropical races of animals, whose remains are now found abundantly in cold climates. Without discussing this question at present, the only elementary question on which geologists differ, we merely hold it up, that it may be seen in the light of the facts which we are briefly to notice.

Classification of Geological Agencies.

Existing agencies may be classed under three heads; the *igneous*, comprehending all the effects of heat; the *aqueous*, comprehending the effects of water in all its forms; and the *organic*, or agency of the animal and vegetable kingdoms.

IGNEOUS AGENCIES.

The crust of the earth has been more or less subjected to the action of heat both from internal and from external sources. The former are the origin of *volcanic action*, using the term in its wider signification, as comprising the kindred phenomena of volcanoes, earthquakes and thermal springs.

"A *volcano* is an opening in the earth, from which matter has been ejected by heat, in the form of lava, scoria, or ashes. Usually the opening called the crater is an inverted cone; and around there arises a mountain in the form of a cone, with its apex truncated, produced by the elevation of the earth's crust and the ejection of the lava."—*Hitchcock.*

Extinct volcanoes are those which have not erupted since the commencement of the historical period, and since they therefore belong to the history of antecedent epochs, the consideration of them is reserved for another place.

Active volcanoes are those which have been known to erupt since the existence of man. A very few of these are in *constant* action, as Stromboli and Kilauea, but the greater part are *intermittent*, with intervals of action varying from a few months to many centuries.

Earthquakes are intimately connected with volcanoes, proceeding from the same general cause, and frequently followed by an eruption, by which these convulsive throes of the earth are relieved.

Thermal springs belong to the same class of phenomena, deriving their temperature from past or present volcanic fires, with which they are always associated.

The facts relating to earthquakes, to thermal springs, and to volcanoes may be classified, as they are *subaërial, submarine,* or *subterranean.**

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* Subaërial from *sub* and *aër*, under the atmosphere; Submarine, from *sub* and *mare*, under the sea; Subterranean from *sub* and *terra*, under the earth.

SUBAERIAL IGNEOUS AGENCY.

VOLCANOES.

There are about 300 volcanoes, of which one-third belong to America, one-third to Oceanica, and the remaining third to Europe, Asia and Africa.

Eruptions.

Usually the first symptoms of an eruption are heard in rumbling sounds, which seem to travel along for a greater or less distance in the depths of the earth; they are seen in the increased volumes of smoke which arise from the crater; and are felt in tremulous motions of the earth, which assume the violence of earthquakes, and bring in their train the horrors that usually accompany these convulsions. Sulphurous and muriatic vapors fill the air, while electric agencies display their vivid coruscations, accompanied with heavy peals of thunder. Unusual signs of fright are manifested by the brute creation. Showers of stones and cinders fall, sometimes in immense profusion, and the convulsions of the earth become more violent. Masses of rock are ejected from the crater with tremendous explosions, until at length the earthquakes cease, and the imprisoned gases and lava find vent through the crater and sometimes through the sides of the volcanic mountain. A river of molten rock streams down and spreads out into a sea of fire. Sometimes its course is slow, sometimes rapid. Glaciers may be encountered and melted, and torrents of boiling water and mud poured down. Showers of cinders again fall and announce the termination of the eruption to be at hand. The flames, explosions, and ejections of rocks and stones become less violent, and finally nothing but vapors and smoke escape from the crater.

Etna and *Vesuvius* have been observed from remote antiquity, and the earthquakes and eruptions of the former were described by the earliest historians and poets. Before the Christian era, Vesuvius was in a state of inactivity. History had no records of its eruptions, and a naturalist only, as he observed the volcanic nature of the rocks, would have suspected its real character. Its energies found vent in the neighboring isles of Ischia and Procida, which were shaken by terrific convulsions and desolated by eruptions. But Vesuvius itself was silent, and although Strabo perceived its volcanic character, Pliny omitted it in his list of active volcanoes. In the cone were the remains of an ancient crater nearly filled up, and covered on its interior with wild vines. At the bottom was a sterile plain, on which Spartacus once encamped with his army of 10,000 gladiators, whose descent was a more disastrous eruption than the fiery floods of later years. The mountain was flanked with fruitful fields highly cultivated, and at its base were the luxurious and populous cities of Herculaneum and Pompeii.

In 63 A. D., Vesuvius gave signs of awakening from its repose of unknown ages. From that year to 79 A. D. shocks were frequent, and at length became more violent, when a terrific eruption took place, and buried the cities above mentioned. Since that time its eruptions have been numerous, but those of 1631 and 1822 were most remarkable. In 1631 a stream of lava consumed Resina, which was built over the site of Herculaneum, and floods of mud were poured down with terrible devastation. These floods originated in heavy rains which are often produced by volcanic action, and which wash down the cinders and dust until they assume the consistency of mud.

For some time previous to 1822 the crater had been gradually filling up, when it was blown out with awful explosion, to the depth of 2000 feet, and more than 800 feet of the top were blown off.

Etna was meanwhile subject to occasional eruptions. In the year 1669 an immense quantity of the lava overwhelmed 14 towns and villages before reaching Catania. Although the walls of this city were sixty feet high, the lava accumulated until it gained the top, and then poured over in a fiery cascade, destroying a portion of the city. The current continued 15 miles further, when it entered the sea with a depth of 40 feet. The progress of this current had been so slow that the surface had time to cool, so that it advanced by breaking through its walls of crust. Since the commencement of the present century, there have been several eruptions through the sides of the mountain. In 1811, seven openings were formed, each at a lower level successively. In 1819, three out of five such openings united in one, and poured an enormous torrent into the valley 'Del Bove.' Arriving at a precipice, it poured over in a cataract of liquid rock, which cooled in its descent and hardened into solid rocks, dashing against the bottom with an inconceivable crash. This current continued to flow for nine months, when it was found to move at the rate of less than five rods per day.

A late traveller gives the following description of an eruption of Etna seen by night:

"It was about half past ten when we reached the foot of the craters, which were both tremendously agitated; the great vent threw up immense columns of fire, mingled with the blackest smoke and sand. Each explosion of fire was preceded by a bellowing of thunder in the mountain. The smaller mouth was much more active: and the explosions followed each other so rapidly that we could not count three seconds between them. The stones which were emitted were fourteen seconds in falling back to the crater; consequently there were always five or six explosions—sometimes more than twenty—in the air at once. These stones were thrown up perpendicularly, in the shape of a wide-spreading sheaf, producing the most magnificent effect imaginable. The smallest stones appeared to be of the size of cannon balls; the greater were like bomb-shells; but others were pieces of rock, five or six cubic feet in size, and some of the most enormous dimensions; the latter generally fell on the ridge of the crater, and rolled down its sides, splitting into fragments as they struck against the hard and cutting masses of cold lava. The smoke emitted by the smaller cone was white, and its appearance inconceivably grand and beautiful; but the other crater, though less active, was much more terrible; and the thick blackness of its gigantic volumes of smoke partly concealed the fire which it vomited. Occasionally both burst forth at the same instant and with the most tremendous fury; sometimes mingling their ejected stones.

If any person could accurately fancy the effect of 500,000 sky-rockets darting up at once to a height of three or four thousand feet, and then falling back in the shape of red-hot balls, shells, and large rocks of fire, he might have an idea of a single explosion of this burning mountain; but it is doubtful whether any imagination can conceive the effect of one hundred of such explosions in the space of five minutes, or of twelve hundred or more in the course of an hour, as we saw them!"—*Mantell.*

In Iceland have occurred some of the most extensive eruptions on record. Most of this island, which is 300 miles long and 150 broad, is covered with volcanoes and vast regions of lava, rugged and torn into broken and pointed rocks, or cleft into yawning chasms of many miles in length, and unseen depth. Other parts of the island are filled with innumerable springs spouting forth torrents of boiling water, or with immense mountains of ice. The convulsions of 1783 appear to have been most violent and on a scale of extraordinary magnitude. Multitudes of the wretched inhabitants perished in the almost general wreck of organic nature. In an eruption of Skaptar Jokul, two streams of lava flowed off in opposite directions, of which one was 40 miles long and seven broad, and the other was 50 miles long and 12 broad; both containing 70,000,000,000 cubic yards.

On Hawaii, (Sandwich Is.), is an ever active volcano, *Kilauea*, of unusual form and situation. The crater is not in a truncated cone of a mountain, but in an upland country, near the base of Mouna Roa, which rises to a height of 16,000 or 18,000 feet above the level of the sea. The crater is an immense chasm, in the middle of a plain, which is surrounded by a precipice from 200 to 400 feet high, and is 15 miles in circumference. Or rather this plain is itself a chasm, and the crater is a chasm within a chasm.

Mr. Stewart, formerly missionary at these islands, gives an interesting account of its appearance.

"Standing at an elevation of 1500 feet, we looked into a horrid gulf, not less than eight miles in circumference, directly beneath us. The hideous immensity itself, independent of the many frightful images embraced in it, almost caused an involuntary closing of the eyes against it. But when to the sight is added the effect of the various unnatural and frightful noises, the muttering and sighing, the groaning and bellowing, the every agonized struggling of the mighty action within, as a whole it is too horrible. This gulf contains 50 or 60 conical craters, many of which are in constant action. About half way down the perpendicular side of the chasm is a ledge or piazza of lava from a few feet to several yards in width, which extends all around. Below this, all was of a dismal black color, except two or three of the conical craters at the bottom, which were covered with sulphur of various shades of yellow and green. The cliffs above the piazza were red on the north and and west sides; on the east the bank was less precipitous, and consisted of entire banks of sulphur of a delicate and bright yellow.

As the darkness of the night gathered around us, fire after fire began to glimmer on the eye, appearing in rapid succession. Two or three small craters were in full action, every moment casting out stones, ashes, and lava, with heavy detonations, while the irritated flames glared over the surrounding obscurity, richly illuminating the more distant volumes of smoke. The great seat of action, however, seemed to be in the southern and western end, where an exhibition of ever-varying fire-works was presented. Rivers of fire were seen rolling in splendid coruscations among the laboring craters. During the second night, the noises were redoubled, rolling from one end of the vast chasm to the other with inconceivable velocity, and the flames burst from a large cone, which in the morning appeared to have been long inactive. Red hot stones, cinders, and ashes were propelled to an immense height, and soon the lava boiled over in two curved streams glittering with indescribable brilliancy.

A whole lake of fire opened in a more distant part, two miles in circumference. Its surface had all the agitation of an an ocean; billow after billow tossed its monstrous bosom in the air and occasionally met with such violent concussion as to dash the fiery spray 40 or 50 feet high."*

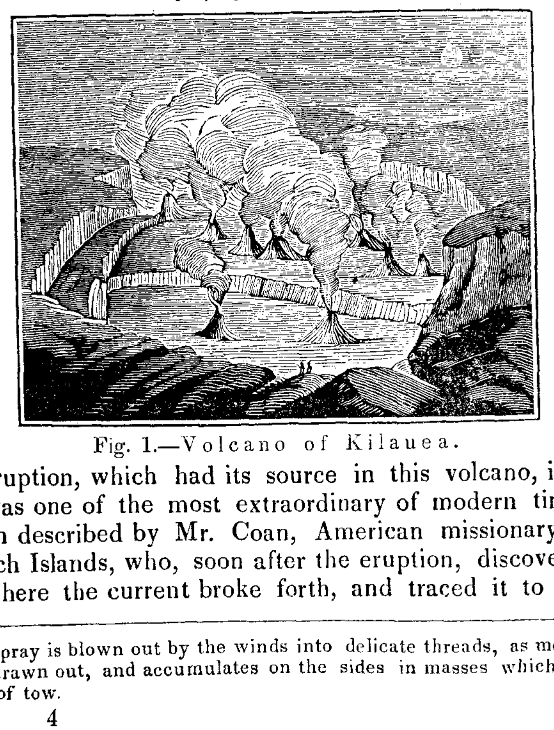


Fig. 1.—Volcano of Kilauea.

An eruption, which had its source in this volcano, in June, 1840, was one of the most extraordinary of modern times. It has been described by Mr. Coan, American missionary in the Sandwich Islands, who, soon after the eruption, discovered the place where the current broke forth, and traced it to the sea.

*This spray is blown out by the winds into delicate threads, as melted glass may be drawn out, and accumulates on the sides in masses which resemble bunches of tow.

We give his narrative, although rather long, as furnishing one of the most instructive examples of this class of geological agencies.

"For several years past the great crater of Kilauea has been rapidly filling up, by the rising of the superincumbent crust, and by the frequent gushing forth of the molten sea below. In this manner the great basin below the black ledge, which has been computed from three hundred to five hundred feet deep, was long since filled by the ejection and cooling of successive masses of the fiery fluid. These silent eruptions continued to occur at intervals, until the black ledge was repeatedly overflowed, each cooling, and forming a new layer from two feet thick and upwards, until the whole area of the crater was filled up, at least fifty feet above the original black ledge, and thus reducing the whole depth of the crater to less than nine hundred feet. This process of filling up continued till the latter part of May, 1840, when, as many natives testify, the whole area of the crater became one entire sea of ignifluous matter, raging like old ocean when lashed into fury by a tempest. For several days the fires raged with fearful intensity, exhibiting a scene awfully terrific. The infuriated waves sent up infernal sounds, and dashed with such maddening energy against the sides of the awful caldron, as to shake the solid earth above, and to detach huge masses of overhanging rocks, which, leaving their ancient beds, plunged into the fiery gulf below. So terrific was the scene that no one dared to approach near it, and travellers on the main road, which lay along the verge of the crater, feeling the ground tremble beneath their feet, fled and passed by at a distance. I should be inclined to discredit the statements of the natives had I not since been to Kilanua and examined it minutely with these reports in view. Every appearance, however, of the crater confirms them. Every thing within the caldron is new. Not a particle of the lava remains as it was when I last visited. All has been melted down and recast. The whole appears like a raging sea, whose waves have been suddenly solidified while in the most violent agitation.

Having stated something of the appearance of the great crater for several days before the disgorgement of its fiery contents, I will now give a short history of the eruption itself. I say short, because it would require a volume to give a full and minute detail of all the facts in the case. On the 30th of May, the people of Puna observed the appearance of smoke and fire in the interior, a mountainous and desolate region of that district. Thinking that the fire might be the burning of some jungle, they took little notice of it until the next day, sabbath, when the meetings in the different villages were thrown into confusion by sudden and grand exhibitions of fire, on a scale so large and fearful as to leave them no room to doubt the cause of the phenomenon. The fire augmented during the day and night; but it did not seem to flow off rapidly in any direction. All were in consternation, as it was expected that the molten flood would pour itself down from its height of four thousand feet to the coast, and no one knew to what point it would flow, or what devastation would attend its fiery course. On Monday, June 1st., the stream began to flow off in a northeasterly direction, and on the following Wednesday, June 3d., at evening, the river reached the sea, having averaged about half a mile an hour in its progress. The rapidity of the flow was very unequal, being modified by the inequalities of the surface, over which the stream passed. Sometimes it is supposed to have moved five miles an hour, and at other times, owing to obstructions, making no apparent progress, except in filling up deep valleys, and in swelling over or breaking away hills and precipices.

But I will return to the source of the eruption. This is in a forest, and in the bottom of an ancient wooded crater, about four hundred feet deep, and probably eight miles east from Kilauea. The region being uninhabited and covered with a thicket, it was some time before the place was discovered, and up to this time, though several foreigners have attempted it, no one, except myself, has reached the spot. From Kilauea to this place the lava flows in a

subterranean gallery, probably at the depth of a thousand feet, but its course can be distinctly traced all the way, by the rending of the crust of the earth into innumerable fissures, and by the emission of smoke, steam and gases. The eruption in this old crater is small, and from this place the stream disappears again for the distance of a mile or two, when the lava again gushed up and spread over an area of about fifty acres. Again it passes under ground for two or three miles, when it reappears in another old wooded crater, consuming the forests, and partly filling up the basin. Once more it disappears, and flowing in a subterranean channel, cracks and breaks the earth, opening fissures from six inches to ten or twelve feet in width, and sometimes splitting the trunk of a tree so exactly that its legs stand astride at the fissure. At some places it is impossible to trace the subterranean stream, on account of the impenetrable thicket under which it passes. After flowing under ground several miles, perhaps six or eight, it again broke out like an overwhelming flood, and sweeping forest, hamlet, plantation, and every thing before it, rolled down with resistless energy to the sea, where, leaping a precipice of forty or fifty feet, it poured itself in one vast cataract of fire into the deep below, with loud detonations, fearful hissings, and a thousand unearthly and indiscribable sounds. Imagine to yourself a river of fused minerals, of the breadth and depth of Niagara, and of a gory red, falling, in one emblasoned sheet, one raging torrent, into the ocean! The scene, as described by eye witnesses, was terribly sublime. Two mighty agencies in collision! Two antagonist and gigantic forces in contact, and producing effects on a scale inconceivably grand! The atmosphere in all directions was filled with ashes, spray, gases, etc., while the burning lava, as it fell into the water, was shivered into millions of minute particles, and, being thrown back into the air, fell in showers of sand on all the surrounding country. The coast was extended into the sea for a quarter of a mile, and a pretty sand beach and a new cape were formed. Three hills of scoria and sand were also formed in the sea, the lowest about two hundred, and the highest about three hundred feet.

For three weeks this terrific river continued to disgorge itself into the sea with little abatement. Multitudes of fishes were killed, and the waters of the ocean were heated for twenty miles along the coast. The breadth of the stream, where it fell into the sea, is about half a mile, but inland it varies from one to four or five miles in width, conforming itself, like a river, to the face of the country over which it flowed.

The depth of the stream will probably vary from ten to two hundred feet, according to the inequalities of the surface over which it passed. During the flow, night was converted into day on all eastern Hawaii. The light rose and spread like the morning upon the mountains, and its glare was seen on the opposite side of the island. It was also distinctly visible for more than one hundred miles at sea, and at the distance of forty miles fine print could be read at midnight. The brilliancy of the light was like a blazing firmament, and the scene is said to have been one of unrivalled sublimity.

The whole course of the stream from Kilauea to the sea is about 40 miles. Its mouth is about 25 miles from Hilo station. The ground over which it flowed descends at the rate of one hundred feet to the mile. The crust is now cooled, and may be traversed with ease, though scalding steam, pungent gases, and smoke are still emitted in many places.

In pursuing my way for nearly two days over this mighty smouldering mass, I was more and more impressed, at every step, with the wonderful scene. Hills had been melted down like wax; various and deep valleys had been filled; and majestic forests had disappeared like a feather in the flames. In some places the molten stream parted and flowed in separate channels for a great distance, and then reuniting formed islands of various sizes, from one to fifty acres, with trees still standing, but seared and blighted by the intense heat. On the outer edges of the lava, where the stream was more shallow, and the heat less vehement, and where of course the liquid mass cooled soonest, the trees were mowed down like grass before the scythe, and left charred, crisped, smouldering, and only half consumed. As the lava flowed around the trunks of large trees on the outskirts of the stream, the melted mass stiffened and consolidated before the trunk was consumed, and when this was effected, the top of the tree fell, and lay unconsumed on the crust, while the hole which marked the place of the trunk remains almost as smooth and perfect as the calibre of a cannon. These holes are innumerable, and I found them to measure from ten to forty feet deep, but, as I remarked before, they are in the more shallow parts of the lava, the trees being entirely consumed where it was deeper. During the flow of this eruption, the great crater of Kilauea sunk about three hundred feet, and her fires became nearly extinct, one lake only out of many being left active in this mighty cauldron. This, with other facts which have been named, demonstrates that the eruption was the disgorgement of the fires of Kilauea. The open lake in the old crater is at present intensely active, and the fires are increasing, as is evident from the glare visible at our station and from the testimony of visitors.

While the stream was flowing, it might be approached within a few yards on the windward side, while at the leeward no one could live within the distance of many miles, on account of the smoke, the impregnation of the atmosphere with pungent and deadly gases, and the fiery showers which were constantly descending and destroying vegetable life. During the progress of the descending stream, it would often fall into some fissure, and forcing itself into apertures and under massive rocks, and even hillocks and extended plats of ground, and lifting them from their ancient beds, bear them with all their superincumbent mass of soil, trees, etc. on its viscous and livid bosom, like a raft on the water. When the fused mass was sluggish, it had a gory appearance like clotted blood mingled and thrown into violent agitation.

Sometimes the flowing lava would find a subterranean gallery, diverging at right angles from the main channel, and pressing into it would flow off unobserved, till meeting with some obstruction in its dark passage, when, by its expansive force, it would raise the crust of the earth into a dome-like hill of fifteen or twenty feet in height, and then bursting this shell, pour itself out in a fiery torrent around. A man who was standing at a considerable distance from the main stream, and intently gazing on the absorbing scene before him, found himself suddenly raised to the height of ten or fifteen feet above the common level around him, and he had but just time to escape from his dangerous position, when the earth opened where he had stood, and a stream of fire gushed out."—*Coan.*

Another illustration we quote from Mr. Lyell's Principles of Geology.

"In April, 1815, one of the most frightful eruptions recorded in history occurred in the mountain *Tomboro*, in the island of Sumatra. It began on the 5th of April, and was most violent on the 11th and 12th, and did not entirely cease till July. The sound of the explosions was heard in Sumatra, at the diatance of 970 geographical miles in a direct line, and at Ternato, in an opposite direction, at the distance of 720 miles. Out of a population of twelve thousand, only twenty-six individuals survived on the island. Violent whirlwinds carried up men, horses, cattle, and whatever else came within their influence, into the air; tore up the largest trees by their roots, and covered the whole sea with floating timber. Great tracts of land were covered with lava, several streams of which, issuing from the crater of the Tomboro mountains, reached the sea. So heavy was the fall of ashes, that they broke into the President's house at Birna, forty miles east of the volcano, and rendered it, as well as many other dwellings in town, uninhabitable. On the side of Java the ashes were carried to the distance of 300 miles, and 217 towards Celebes, in sufficient quantity to darken the air.

The floating cinders to the windward of Sumatra formed, on the 12th of April, a mass two feet thick, and several miles in extent, through which ships with difficulty forced their way.

The darkness occasioned in the day time by the ashes in Java was so profound, that nothing equal to it was ever witnessed in the darkest night.

The area over which the tremulous noises and other volcanic effects extended, was one thousand English miles in circumference, including the whole of the Molucca islands, Java, and a considerable portion of Celebes." —*Lyell.*

Static pressure in Volcanoes.

The enormous pressure of the liquid lava against the interior of volcanoes, when it is raised to a great height, is the cause of the frequent eruption through their sides. The force requisite to raise lava to the edge of the crater of Ætna, from the level of the base of the mountain, exceeds five tons per square inch. In Cotopaxi, one of the highest of all volcanoes, being 19,000 feet in height, the force required is ten tons per square inch: yet this volcano has projected matter 6000 feet above its summit, and once threw a stone weighing 200 tons to the distance of nine miles. Aconcagua in Chile has a height of 23,000 feet, and would therefore require at its base, for an eruption from the summit, a force of nearly 14 tons per square inch.

Characters of Lava.

The melted matter ejected from volcanoes is composed chiefly of feldspar and augite. When the former prevails the lava is said ot be feldspathic or trachytic, and when the latter predominates the lava is said to be augitic. When lava is cooled near the surface of the mass, it is usually light and porous, having been inflated with bubbles of gas. In some cases these bubbles of gas are of great size, and the cavities constitute large caverns. Sometimes the elasticity of the gas explodes the bubbles and throws fragments of lava into the air. When melted feldspathic lava comes into contact with water, the water is converted into steam, which occasions the lava to froth up, and converts it into *pumice*. At the time of the eruption of Skaptar Jokul in 1783, there was an island thrown up seventy miles from land, when the ocean was covered with vast quantities of floating pumice, for a distance of 150 miles. My friend Dr. C. T. Jackson has informed me that he has made pumice from the slags of furnaces by throwing water in the path of the running slag. It is indeed a common form of the slag of furnaces.

When lava cools under the pressure of a superincumbent mass, it is generally as compact and solid as the older rocks. Some of the products of volcanoes consist mostly of silex, and resemble impure glass or the slag of furnaces, and frequently the artificial cannot be distinguished from the natural product.

Earthquakes.

One of the most remarkable earthquakes was that which began at *Lisbon* on the 1st November, 1755. A sound, like thunder under ground, was heard, and in six minutes the greater part of the city was thrown down, and 60,000 persons had perished. The sea retired, and then rolled back 50 feet higher than its ordinary level. A new marble quay was suddenly swallowed up with a great concourse of people, and the vortex drew down many boats and small vessels. The highest mountains in Portugal were shaken from their foundations, opened their summits, were split and rent, and portions of them thrown down into the valleys. The shock was felt at sea, and a ship 120 miles west of St. Vincent experienced a violent concussion, which was probably occasioned by a wave of translation, that is, a motion of the water itself.

This earthquake was felt over a large part of the earth. All Europe, even to Norway, felt the shock. The waters of Loch Lomond (in Scotland) rose two feet and four inches. Terrible eruptions and earthquakes occurred in Iceland. Springs throughout Europe and Great Britain became hot, and some of them turbid. The North of Africa was violently shaken, and a village was engulphed with 8,000 or 10,000 persons. The shock was felt in the West Indies; and the waters of Lake Ontario were violently shaken.

The *West Indies* have been more or less subject to earthquakes since their discovery. In 1692 a great earthquake engulphed three quarters of the large and opulent city of Port Royal in Jamacia; the Blue Mountains, 8000 feet high, were rent and shattered, and the surface of the island swelled and heaved like a rolling sea. In 1843, Gaudaloupe and several towns were suddenly destroyed.

The *motion* of the ground in earthquakes is said to be like that of waves pursuing each other with great velocity, in many cases of 20 miles per minute. Sometimes the force acts in an upward direction, as in the earthquake of Calabria in 1783, when loose masses bounded into the air to the height of several yards, and in some of the towns the pavements were thrown up. During the same earthquake however, other places were affected with a force acting horizontally.

The effects of *earthquakes*, most important in a geological point of view, are the subsidence and the elevation of land. In the year 1772, Papandayang, one of the loftiest volcanoes of Java, was in eruption, when the greater part of the mountain, for a space of 15 miles long and 6 wide, fell in and disappeared with its inhabitants. On the other hand, the bed of the sea, in the harbor of Conception (Chile), was raised, in 1750, to the amount of 25 feet, and in 1822 the coast of Chile was permanently elevated through an area of 100,000 square miles.

Elevation of land in some cases is going on gradually, without any apparent earthquake shocks. This is remarkably the case with the country around the Baltic Sea, which is rising at the rate of two or three feet per century, as shown by the marks made at various periods to designate the high water level, and confirmed by the marine shells of species now living on the shore, which are found from 10 to 200 feet above the present level of the water and 50 miles inland.

The coast of Greenland appears to be undergoing a gradual depression. In this country the northern states appear to have been rising during a geological period not very remote, and perhaps the process is yet slowly going on.

Thermal Springs.

Geysers, or springs of hot water, occur in volcanic countries. The most celebrated are those of Iceland, in the southwest part of which is an assemblage of perforations in the earth, through which are emitted jets of boiling water. The Great Geyser, 8 or 10 feet in diameter, perforates a basin-shaped mound, through which a column of water of this diameter is frequently ejected, by an intermittent force, to the height of 150 or 200 feet, dividing into the most superb curvate ramifications, and throwing off shoots in oblique directions, whose falling jets endanger the spectator.

Hot springs are also common in countries which are quite remote from any existing volcanic agency, but which at no very remote geological period have been the theatre of volcanic action. In Arkansas and in Oregon are examples.

In some cases the heat is that of boiling water, but there are all degrees of temperature, and the thermal character of some springs is so slight as to be detected only by continued thermometrical observations.

In most if not in all cases, thermal springs, which are distant from active volcanoes, are situated near ancient volcanic rocks or near chains of mountains, which were broken up and elevated by the igneous agency of former epochs.

SUBMARINE IGNEOUS AGENCY.

Volcanic Islands.

Many islands of considerable size have been seen to rise from the sea, and many others composed of lava, are doubtless of volcanic origin. The Mediterranean Sea only having been observed by the ancients, authentic narratives of such events in remote ages are limited to that sea. In the Grecian Archipelago is a group of islands, of which *Santorini* is the chief, several of which have been thrown up at different times.

In July 1831, a volcano rose up through the sea off the coast of Sicily, and was called *Graham's Island.* In August it was 180 feet high, and one and one-third miles in circumference: but the part above the water being composed of loose materials, it disappeared in two or three years, leaving a rocky shoal. The Azores have been repeatedly increased by new volcanic islands, and also the Aleutian isles. In 1814, near Unalaschka an island was raised with a peak 3000 feet high. Many new islands have been thrown up near the shores of Iceland, and some of them have since subsided. The one alluded to on page 29 consisted of high cliffs, and was claimed by the king of Denmark. But Neptune appears to have been the successful claimant.

Submarine earthquakes not infrequently furnish proofs of their occcurrence in sudden and extraordinary waves. A few years since at the Sandwich Islands, a series of such waves swept away a village near the shore. Perhaps a sudden rise and fall of one or two feet, which was observed in the harbor of Nantucket, in June, 1836, may be referred to such a cause.

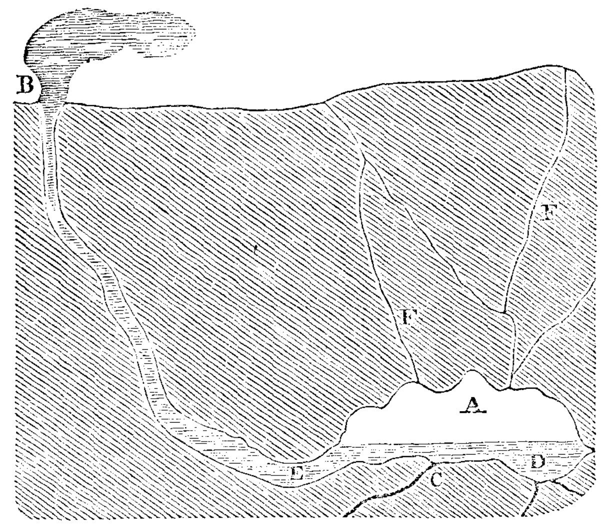
What volcanic forces may be active in the lowest depth of the ocean, who shall say? At the depth of five miles, the pressure of the superincumbent mass of water would be so great that the most powerful volcanic agency would act silently and be unfelt at the surface. With that pressure the water would become red hot without bursting into steam, and currents of incandescent lava might flow quietly down the sides of submarine mountains. But the effects on the chemical constitution and crystalline structure of the melted and cooling mass would be great.

SUBTERRANEAN IGNEOUS AGENCY.

The history of igneous agency on the surface of the earth naturally leads us to look within for its source. We shall briefly proceed from the less to the more general conclusions, until we arrive at a theory sufficiently comprehensive to embrace all the phenomena of igneous action.

The most probable *theory of geysers* has been well illustrated by the following figure, (see Lyell's Principles; Am. Ed. I. 472.)

Fig. 2.



"Suppose water percolating from the surface of the earth to penetrate into the subterranean cavity A D by the fissures F F, while at the same time steam at an extremely high temperature, such as is commonly given out from the vents of lava currents during congelation, emanates from the fissures C. A portion of the steam is at first condensed into water, while the temperature of the water is elevated by the latent heat thus envolved, till at last the lower part of the cavity is filled with boiling water and the upper part with steam under high pressure. The expansive force of the steam becomes at length so great that the water is forced up the fissure E B, and runs over the rim of the basin. When the pressure is thus diminished, the steam in the upper part of the cavity A expands, until all the water D is driven into the pipe: and when this happens the steam also rushes up with great velocity."

The same theory may be applied to volcanoes, if we suppose that the seat of operations is at the depth of several miles, on a mass of molten lava, where water entering is converted into steam which forces up the lava in the crater of some neighboring volcano or through the crust of the earth. That water is an important agent in volcanic eruptions would seem to be proved by the great quantities of steam which escape, and by the hydrochloric acid and salt emitted, which the salt water may have furnished. In South America even fishes have been discharged.

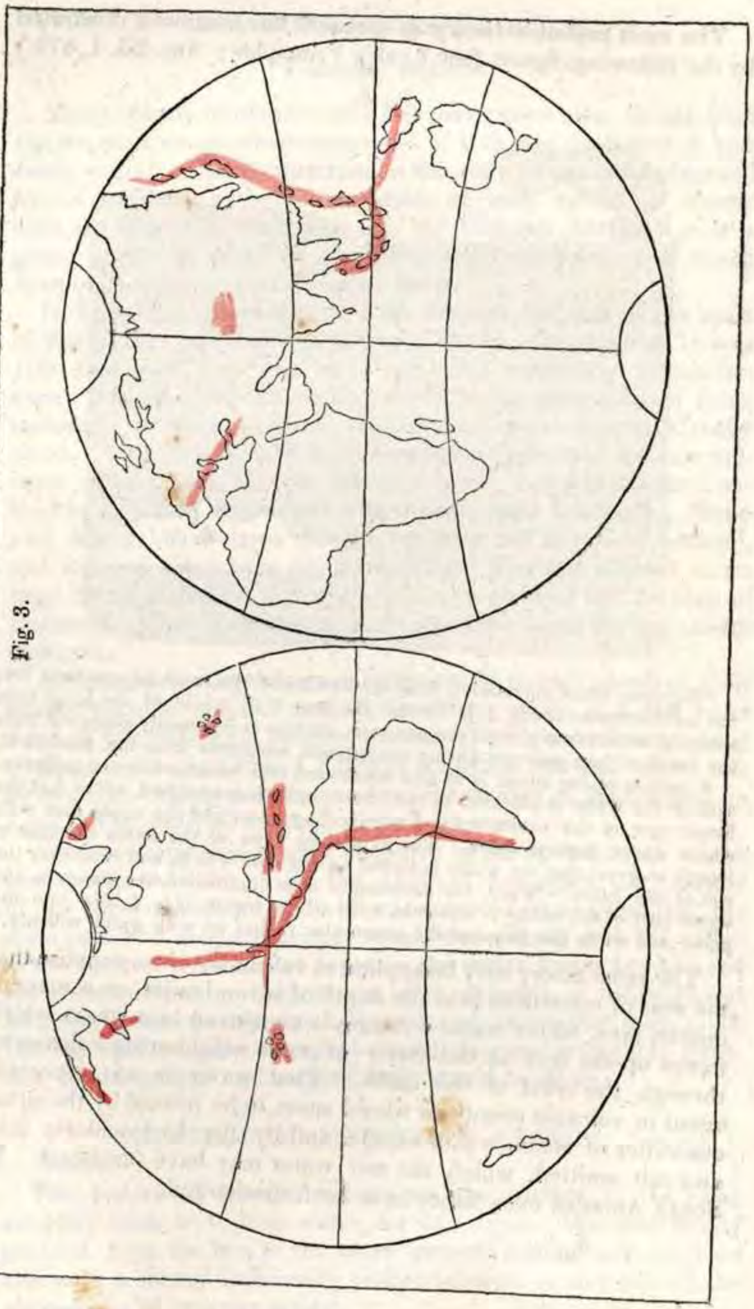


Fig. 3.

The geographical distribution of volcanoes tends to the same conclusion. On inspection of the accompanying map (fig. 3.) on which the volcanic regions are indicated by the red color, it will be seen that volcanoes are, with few exceptions, situated near the ocean. About two-thirds of the number are on islands, and of the remaining third nearly all are within a short distance of the coast. In Mexico and in central Asia there are a few exceptions to this general statement. It will be seen also that most volcanoes are arranged in lines or zones of great extent.

It may perhaps be objected to any theory, which shall make the expansive force of steam the sole agency, by which lava is elevated many thousand feet,—that the force may not be sufficient. At a temperature of 800°, nearly a red heat, water only doubles its volume, when converted into steam, with a pressure of two tons per square inch. And as the pressure of lava in most volcanoes exceeds this amount, it would seem that the ordinary source of the great power of steam by increase of heat, viz. the increased quantity in a given space, would avail little. The resistance of the superincumbent matter would be such that the water would not double its bulk. The universal law of expansion by increments of heat would hold good, but although the application of the law under such circumstances may not be obvious, yet it may be conjectured that the water would merely be heated red hot without an very considerable expansion.

The history of volcanoes and earthquakes shows us that the source of their action is very deeply seated in the earth. This is especially mauifest from the *quantity of matter erupted*. The single eruption of Skaptar Jokul in 1783 protruded a mass of lava exceeding the bulk of the entire mountain. In 1660 it was computed that the ejections of Mount Etna, if collected, would form a mass twenty times the size of the original mountain ; yet the subsequent eruptions do not indicate any exhaustion of the source. It was therefore a correct idea of Seneca, who says that the volcanic mountain does not supply the fire, but merely affords it a passage. Volcanoes are only chimneys over the subterranean fires.

But we may go farther, and affirm that these fires are sufficiently extensive to furnish a communication between distant volcanoes. This conclusion unavoidably follows from their mutual *alternation and eruption*, from theit relations to earthquakes, and from the geographical extent of the latter. Out of the numerous facts, which sustain this conclusion, we can present only illustrations.

In 1797 the volcano of Pasto, in the west part of Columbia, emitted a volume of smoke for three months, which ceased at the moment when a violent earthquake, with an eruption of mud and water, of vapors and flames, occurred at the distance of 180 miles. Vesuvius and Ischia alternate with each other. Eruptions of the latter were frequent and violent in the earlier ages, while Vesuvius was quiet until A. D. 73, when it overwhelmed Herculaneum and Pompeii. Ischia has since had its period of repose, and Vesuvius, of activity.

It has been observed that from the commencement of the thirteenth to the latter half of the seventeenth century, earthquakes in Syria and Judea almost entirely ceased, while southern Italy suffered extraordinary convulsions. A comparison of their history leads to the conclusion that both are not violently affected at the same time, whence it has been inferred that a subterranean connection exists between regions nearly 1500 miles distant.

In 1811, South Carolina was convulsed with earthquakes, which continued until Laguira and Caraccas (South America) were destroyed. At the same time the valley of the Mississippi was convulsed, especially near New Madrid. New lakes, 20 miles in extent, were formed, and others drained; the earth undulated like the ocean, and split into frightful chasms. These chasms were in a direction from south west to north east, and the people, soon observing it, felled trees at right angles to this direction, and placed themselves upon them. Many were thus saved from being swallowed up.

The direction of these chasms was that which would have been produced by an undulating force, propogated in a north-west and south-east line; and it is worthy of notice that New Madrid in the valley of the Mississippi, South Carolina, and Caraccas are nearly in this direction. This circumstance, and especially the coincidence in time, indicate a subterranean communication between these places, whose extremes are distant 2500 miles.

The extent, to which the earthquake of 1755 was felt, has been mentioned, (p. 30), and indicates a seat of subterranean action under a very considerable portion of the crust of the earth.

The influence of earthquakes may be considerably extended by the transmission of vibrations through the solid rocks. But the extent of country affected in this manner cannot be greatly disproportioned to that which is directly acted upon. A mere transmitted vibration could not effect the *quantity* and *temperature* of the waters in thermal springs and render them turbid, which was remarkably the case throughout Europe in the Lisbon earthquake.

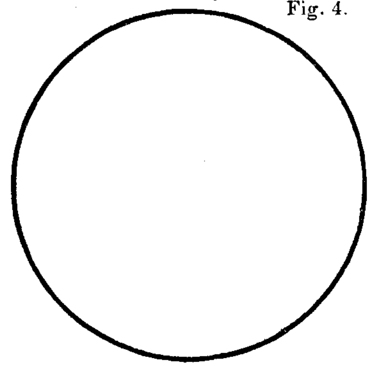
Says Baron Humboldt, in the view of such facts,

"They demonstrate that these forces act, not superficially in the outward crust of the earth, but at immense depths in the interior of our planet."

Theory of Internal Heat.

Thus far geologists are agreed; but if we extend our inquiries further and require a more definite theory of the source of volcanic fires, we then find some difference of opinion. Let us consider the theory which is most in favor, and which supposes that the whole interior of the earth is in a state of fusion, within a crust of 50 to 100 miles in thickness. According to this theory earthquakes are the effects of the heaving of this melted interior, occasioned perhaps by steam or chemical action, and volcanoes are the safety valves, through which earthquakes are relieved. The annexed figure of a circle is intended to represent by the thickness of the line of circumference, the thickness of the crust of the earth as compared with the melted interior.

Fig. 4.



In support of this theory it is urged that it affords a satisfactory explanation of the great extent of earthquakes and the alternation between distant volcanoes, of the great quantity of matter ejected through the latter, and of their being associated together along lines or in groups where the crust of the earth may be supposed to be of less thickness. The undulatory motion of earthquakes would be merely the waving of the crust. This theory, however, reposes chiefly on experiments made upon the temperature of mines and artesian wells, which concur in the interesting result, that in all places the temperature of the earth increases after passing below the stratum of surface temperature, in a ratio, which varies in different places from 1° Fahr. for 25 feet of descent, to 1° for 70 feet, but which is quite constant in the same place. From the very numerous observations which have been made, we select a few examples.

"At the Dolcoath mine of Cornwall, (England), the mean annual temperature at the surface of the ground is 50°; of a spring 1440 feet below, 82°; and of the rock three feet three inches within its surface and 1381 feet deep, 76.6°. At the silver mine of Guanaxuato the mean annual temperature at the surface is 68, 8°, and the temperature of a spring 1713 feet below is 98,3°. A single experiment in the deepest coal mine in Great Britain, near Sunderland, gave the following results; depth of the place of observation 1584 feet; below the level of the sea, 1500 feet. Mean annual temperature at the surface, 47.6°; temperature on the day of observation (Nov. 15, 1834) 49°; do. of the air at the bottom of the pit, 64°; close to the coal, 68°; do. of water collected at bottom, 67°; do. of salt water issuing from a hole made the same day, 70. 1°: do. also of gas rising through the water, 72.6°; do. of the front of the coal, 68°. Hence the heat increases at the rate of about a degree for every 60 feet." (*Hk.*)

At Berlin (Prussia) the mean temperature is 47.1°; the temperature of the water of an artesian well at the depth of 675 feet is 67.6°. At Paris the main temperature is 51.1°; the temperature of an artesian well 1800 feet deep (the deepest in the world,) is 83°. In Wurtemburg the water obtained in artesian wells is used with success to prevent the stopping of machinery by the freezing of the water which carries it, and also for warming a paper manufactory.*

As similar results have been obtained in all cases, it is inferred that the heat would be found to continue to increase, if we were able to penetrate much deeper, until at the depth of one or two miles, we should reach the temperature of boiling water.† At the same ratio of increase, the heat at a depth of fifty miles would be sufficient for the fusion of all known rocks.

It has been objected to this theory, that the diffusion of heat through the liquid interior should melt also the crust of the earth. If it were supposed that the heat continued to increase through all the melted nucleus to the centre in the same ratio in which it increases through the solid crust, the objection would be fatal to any *such* theory. But we cannot see any more difficulty in conceiving that the earth has had a crust 50 miles in thickness congealed in the lapse of ages, than that a body of water should be incrusted with ice by a similar process. It might as well be urged that it is impossible for a pond of water to be frozen over, because the diffusion of heat through the water would melt the ice.

Another theory supposes that there are, beneath the crust of the earth, immense reservoirs and subterranean channels of lava, whose action is the source of eruptions and earthquakes. The ground of preference for this theory on the part of its advocates, is, that it is *sufficient* to account for all the phenomena of earthquakes and volcanoes, and of the temperature of mines and artesian wells. If, however, these reservoirs, and channels are thus numerous, the theory is obviously exposed to the objection which has been urged against the former, and the existence of partitions protected from the colder temperature of the surface by miles of non-conducting materials, but exposed to the action of these adjacent lakes of fire, is inconsistent with the laws of the equilibrium of heat in liquids.

AQUEOUS AGENCIES.

The aqueous agencies, which are modifying the surface of the earth may be classified as they are, or are not, *marine*. Those

*Warm springs which rise from deep sources, have been used for warming conservatories, and irrigating garedns. It is said that a piece of ground at Erfurt (Germany) which is thus kept at an equable and high temperature yields to its proprietor an annual profit of $60,000 derived from raising salad.

†On account of the great pressure, it is not to be inferred that water *would* boil at this or any other depth. v. p. 35.

which are not marine are the *atmospheric agencies* of rain and frost; *rivers* with their occasional inundations, aided by ice, and forming deltas; *lakes* bursting through their barriers; *springs* depositing mineral matter on the surface of the ground; and *glaciers*. The marine agencies are waves, tides, oceanic currents, and icebergs.

AQUEOUS AGENCIES, NOT MARINE.

ATMOSPHERIC AGENCIES.

Rain acts chemically on all calcareous rocks. It is well known that water, although when pure it will not dissolve limestone, yet when charged with carbonic acid gas, will dissolve calcareous matter with a facility proportioned to the quantity of gas in the water. Falling rain obsorbs this gas from the air, and thus acquires the power of slowly dissolving the solid rocks in limestone countries. Calciferous rocks exhibit the effect of this action in the irregular furrows which are worn down their inclined sides, and in the generally rounded surfaces of such rocks.

Rains also act mechanically by carrying the loose fragments and particles of the surface of the ground into rivers, thus furnishing them, not only with their liquid but also with their solid contents.

This agency is very striking in some countries, where the rock formations are more or less porous like sandstone, or where they have not been first worn and then protected by Drift. In Jamaica and Antigua there is often an imperceptible gradation of coherence from the loose soil of the surface to the solid rock beneath, and the upper portions of the latter may easily be removed with a spade. Heavy rains falling on the steep sides of mountains of such rocks will therefore carry off immense quantities of matter, and expose fresh portions of rock.

The removal of mineral matter from higher to lower stations is the greater from the fact that a greater quantity of rain usually falls on high than on low lands. Elevated districts being cooler condense a greater portion of the vapor, which is every where present in the atmosphere. This is especially manifest in hot countries, where the intense heat enables the air to contain an immense amount of watery vapor, which is condensed in deluging showers on the cool sides of the mountains.

In cold climates the agency of *frost* more or less compensates for the deficiency of rain in the work of destruction. Water penetrating into porous rocks or entering fissures, and expanding by frost with an irresistible force, crumbles the surface, and throws out large blocks of stone. The fragments lie in enormous heaps at the base of precipices or fall into the beds of mountain torrents and are removed by freshets.

Rivers co-operate in the work by carrying down limestone in solution, thus furnishing the materials for the solid structures of some of the most extensive and interesting organic agencies which we are to notice. Their most obvious action, however, is in the transport of matter merely by mechanical agency. This is much greater than some would suppose, from the fact that mineral substances lose about three-sevenths of their weight in water as compared with their weight in air. A current moving with a velocity of only 300 yards per hour, will tear up fine clay; of 600 yards per hour, will remove fine sand; of two-thirds of a mile per hour, will remove coarse sand; and with a velocity of two miles per hour, will transport stones two inches in diameter. The agency of running water is also multiplied by the friction of the transported fragments upon each other and on the bed of the stream.

One of the most magnificent and instructive examples of the denuding agency of rivers is to be seen in the retrocession of the *Niagara Falls*, which have cut an enormous ravine from Queenstown seven miles back to their present situation. In consequence of the structure of that district, soft shales at the base of the falls underlying the harder limestone, the latter is gradually undermined and these fragments of the overlying rock are detached from above. In this way the falls are now retrograding at a rate not easily reckoned with precision for the want of historical data, but variously estimated to average from one yard to one foot per year. As the rocks have a small dip backwards in the direction of Lake Erie, the falls will at length cease to act on the soft shales, and the process will then be greatly retarded.

The *Ganges* and Burrampooter, descending from the Himalaya mountains, the loftiest on the globe, unite in a vast delta which they have formed. This delta is an extensive alluvial plain, reticulated by an immense number of channels, and is more than twice as large as the state of Vermont. Nothing as coarse as gravel can be found near the Ganges within 400 miles of its mouth. The river has been known to carry away 40 square miles from one district within a few years. Islands of many miles in extent are formed in a short period. Various estimates have been made of the quantity of the solid matter which is carried down by this river; according to the most accurate of which, 35,000 cubic feet of mud pass down every minute during the flood season, or about 3,500,000 tons daily, and the quantity discharged during the 120 days of the flood must therefore amount to 6,000,000,000 of cubic feet. High tides (11 to 16 feet) rapidly disperse this sediment in the Bay of Bengal, whose waters, 100 fathoms deep at 100 miles out, are gradually shoaled from this distance towards

the shore to four fathoms, and for 60 miles are discolored by this turbid stream. The annual discharge of the Ganges would be sufficient to cover a township six miles square with soil to the depth of nearly seven feet.

The delta of the *Nile* is nearly as large as the state of Vermont. Its progress has been arrrested in comparatively modern times by an easterly current in the Mediterranean, which carries off much of the sediment that is discharged into the sea, and preys occasionally upon the delta itself. It is very probable that a bay once occupied the site of the delta, and that it must have been of great depth, for while the sea near the shore gradually deepens to 50 fathoms, it then suddenly falls off to 380 fathoms.

The *Amazon* is probably unequalled among all the powerful agents of degradation. The vast amount carried out by its current, which is not entirely lost in the ocean at the distance of 300 miles from land, is furnishing materials, which, instead of forming a delta, become the subjects of oceanic agents.

The *Mississippi*, the father of waters, has formed most of the lower part of Louisiana, and is forming a tongue of land which extends on each side of it far into the Gulf of Mexico, and which has advanced several leagues since New Orleans was built.

In Massachusetts the matter carried down by the Merrimac has been estimated, from careful experiments by Dr. S. L. Dana, of Lowell, to be 840,000 tons per annum.

The destructive force of occasional floods and storms is worthy of notice. Oceanic deltas are liable to be flooded not only by freshets but by storms from the sea, driving up the tide and current, and when at rare intervals these causes all combine, extensive tracts are entirely remodeled, and vegetable and animal life perish on a scale commensurate with the changes in inorganic nature.

An instructive example of the extraordinary effects of freshets occurred a few years since in Addison County, in this State, of which we shall give an account on some future occasion. It is here mentioned, in passing, because many of our citizens will recollect the disasters of that flood, especially in New Haven. Tropical mountainous regions, like some of the West India Islands, are especially liable, from the heavy rains which fall on the mountains, to very destructive floods, which pour down in continuous cataracts, sweeping along rocks of many tons weight, where ordinarily an insignificant brook only is to be seen. Temporary rivers are then formed where in dry seasons water is entirely wanting.

Masses of ice coöperate powerfully with freshets, choking up the course of the stream, and forming basins of the accumulated waters, which at length burst their barriers, and rush down, tearing up the loose earth in narrow gorges, like Deerfield River in Massachusetts, and grinding over the solid rocks with the noise of thunder. These effects are sometimes seen on a scale which would not have been anticipated.

The tendency of a river flowing through a plain of unconsolidated materials is to form curves, or bends as they are usually called. Wherever the current deviates from a straight line, it strikes the opposite bank, wearing it away, while the comparative quietness of the water on the other side promotes the accumulation of sediment, and the degree of curvature is thus continually increasing. At length in some unusual freshet, the river cuts across the narrowed neck of the bend and forms a new channel. Such bends are numerous on the Mississippi, and are frequently cut off. A few years since a remarkable bend in the Connecticut, in the beautiful alluvial meadows of Northampton, had a circuit of about three miles with a neck of eighty rods, when in a freshet the river cut a deep channel across the neck, leaving its former circuit dry except so far as it still receives a small tributary.

Numerous rivers, in the lower part of their channels, have probably ceased the work of excavation, and when confined by embankment have a tendency to fill up their beds and run at a higher level. The Po and the Adige drain the northern part of Italy, and have caused one hundred miles of coast to encroach twenty miles upon the Adriatic sea within 2000 years. On these rivers the practice of embankment, which commenced in the thirteenth century, has been carried to a great extent. In consequence, the Po has been filled up so much that the surface of the water is higher than the roofs of the houses in the city of Ferrara. The magnitude of these barriers is a subject of increasing expense and anxiety, it having sometimes been found necessary to give them an additional height of one foot in a single season. The Mississippi is confined by levees for a considerable distance above and below New Orleans, and as the Po is comparatively a pigmy, the future inhabitants of Louisiana may expect to find the river rather unmanageable, should it begin to fill its bed and to raise its waters.

Notwithstanding the powerful degradating agency of rivers, they have not in most cases formed the valleys through which they flow. These are usually due to agencies which gave the configuration to the surface of the earth long anterior to the historical epoch. Some rivers, as the Deerfield in Massachusetts, near its mouth, and the Connecticut between Mt. Holyoke and Mt. Tom, and again at Middletown in Connecticut, turn aside from valleys, through which a moderate elevation would send them, to pass through mountain gorges, which must have been made by other agencies. The consideration of the terraces so

frequently seen on the banks of rivers belongs to another geological period.

The bursting of lakes is an agency, which, although occasional and rare, produces powerful effects. This is not the place to describe the well known example of the Runaway pond in Glover in this State, and we introduce for an illustration the case of the frightful deluge which occured in 1818 in the valley of Bagnes in Switzerland. The waters of the Drance were dammed up by the falling of glaciers and avalanches, which formed a barrier 400 feet high and 600 feet wide, above which a lake nearly a mile and a half long accumulated. A bold and persevering engineer tunnelled the dyke so as to meet the surface of the water of the lake, which flowed through, gradually melting down its channel as the water fell in the lake. In this way 330,000,000 cubic feet of water were carried off in three days without damage, when the dyke gave way, and in half an hour 530,000,000 cubic feet of water swept down, running the first 13 miles in thirty-five minutes, and bearing down 400 houses, with trees, rocks and earth. Had it not been for the enterprise of the engineer three times the amount of water might have accumulated before bursting through the dyke.

Landslides frequently occur on mountains, especially in times of freshets, and sometimes fill up the course of streams and occasion floods. Hills of clay are peculiarly liable to slides, which produce contortions in the flexible strata. Avalanches of snow and ice concur in violently removing rocks and earth from the steep sides of mountains into valleys beneath.

The history of *glaciers* has within a few years excited much interest, not only on account of their remarkable effects and mode of action, but because of their supposed applicability on a grand and nearly universal scale to the explanation of the phenomena of Drift:

"Glaciers are masses of ice which are enclosed in Alpine valleys, or are suspended upon the flanks of the mountains which rise into the regions of eternal frost. Being of white color, they appear at a distance like vast streams of snow issuing from lofty summits, and extending into the lower valleys. In the Alps * * * they terminate sometimes as high as 7000 or 8000 feet; but some descend to 300 feet. They are sometimes three miles wide and fifteen long, and their thickness at the lower end varies from 80 to 100 feet, and at the upper end, from 12 to 180 feet. * * * Glaciers are composed of snow that has been more or less melted and again frozen. The lower part becomes pure solid ice; the upper part is composed of a sort of granular snow. * * A new layer is added at least each year, so that the mass is stratified. The upper surface is rough and sometimes covered by pointed masses of ice, called aiguilles or needles. Fissures across the glaciers, 20 or 30 and sometimes even 100 feet wide, are very common, produced by the unequal temperature of different parts of the mass. The slope of glaciers is frequently quite moderate. The lower end of the glacier of Aar, which is 15 miles long, is 3000 feet below the upper end."

"The crests and higher parts of the Alps, which are frequently vast *plateaux*, or table lands, containing 100, 200, or even 300 square miles, are covered with thick continuous masses of ice, though the lofty peaks sometimes rise as volcanic mountains from the ocean. These *plateaux* are denominated *mers de glace* or seas of ice, and from which the glaciers originate. The *mers de glace*, by expansion, send down the streams of ice, which continue to descend until they are melted. The common opinion, that the glaciers slide down the mountain by their weight is found to be incorrect; as they are not detached from the *mer de glace;* and it is only the lower part, where the ground is thawed beneath, that slides over the surface, and that by the expansion of the "water freezing in the fissures." In the winter they do not slide at all on their bottom."

"As glaciers advance by expansion, they break off masses of rock from the sides and bottoms of the valleys, and crowd along whatever is moveable, so as to form large accumulations of detritus in front and along their sides. When the glacier melts away, these ridges remain, and are called *moraines.*"

"Although the inferior surface of the glacier is pure smooth ice, yet it is usually thickly set with fragments of rock, pebbles and course sand, firmly frozen into it, which make it a huge rasp; and when it moves forward, these projecting masses, pressed down by the enormous weight of the glacier, wear down and scratch the solid rocks; or when the materials in the ice are very fine, they smooth and even polish the surface beneath. The moveable materials beneath the ice are crushed and rounded, and often work into sand and mud. The rocks in place, against which the glacier presses, are also smoothed and striated upon their sides. These striæ wherever found, are perfectly parallel to one another, because the materials producing them are fixed in the bottom of the ice. But as the glacier advances and retreats, new sets of scratches will be produced, which sometimes cross those previously made at a small angle." (Hk.)

The causes of *springs* and the circumstances which modify their action, are strictly geological, but as this portion of the subject is one of great economical importance, we shall reserve it for future consideration under the head of Economical Geology. We are here to consider springs only as agents of geological changes.

Springs act chiefly by taking up mineral matter at various depths and afterwards depositing it on the surface of the ground. The deposits of greatest magnitude which are thus formed are calcareous or siliceous. We have already remarked that water containing carbonic acid has the property of dissolving limestone. Now the quantity of this gas which water is capable of containing depends upon pressure. Under the pressure of the atmosphere it may contain its own volume; if the pressure be doubled, it will take up double its volume and so on, and to any additional amount in exact proportion to the pressure. Consequently, at some distance within the surface of the earth, springs may, and especially in limestone countries do, contain a great amount of this gas. Hence the subterranean passages of such water through fissures in limestone enlarges those fissures, so that in many cases rivers of considerable size flow under ground, as in Jamaica, which after flowing on the surface for miles have been lost in limestone chasms. Caverns of greater or less size are formed by

the same agency, for caves of any considerable extent are almost invariably in limestone districts.

The water, if overcharged with gas and limestone, that is, containing more than the mere pressure of the air will permit, must deposit the excess of limestone when it issues either into an open cavern or upon the surface of the ground. When it drops from the roof of a cavern, *stalactites* are formed, like icicles pendent from the roof, and masses of *stalagmite* on its floor, and sometimes these meet, forming a column, which is continuous from the floor to the roof of the cavern. Sometimes these masses, especially the stalactites, are of a beautiful crystalline structure; the stalagmite is more frequently in thin concentric but irregular layers, a result of the mode of its deposition. Masses of the latter have been seen, in many countries, rising up like altars 10 or 12 feet high, and 15 feet in diameter. Slabs of beautiful calcareous alabaster are obtained from such stalagmite.

The most extensive deposits of this kind are formed where the springs issue on the surface of the ground. At San Filippo in Italy the springs have deposited a mass of limestone 250 feet thick, and extending a mile and a quarter, when the calciferous waters are diluted by another stream, and the portion of limestone not before deposited is carried into the sea. These springs have been known to deposit a solid mass 30 feet thick in 20 years. The geologist is familiar with numerous cases like this. Frequently the calcareous deposits of springs are more or less filled with irregular pores, and the mass is then called *tufa*. Numerous examples occur in this State which will be described in their place. Plants and any other bodies, lying in the water of such springs, are liable to be coated with the deposit, and such cases of mere incrustation are sometimes confounded with petrifaction, which is an entirely different process.

Deposits of siliceous matter, often called *siliceous sinter*, are the product of hot springs. If water contain an alkali, as soda, it is capable, especially at a high temperature, of dissolving silex, which is deposited when the spring comes to the surface. The basin of the Great Geyser in Iceland has been formed in this manner. Siliceous incrustations are formed on plants in the same manner as the calcareous incrustations above mentioned. Such deposits are less numerous and extensive than those which are calcareous, but of much interest, as shewing us how water may dissolve rocks of flint.

OCEANIC AGENCIES.

The materials which are borne along by rivers, if not deposited along their course, are consequently carried into lakes, seas, and oceans and distributed in sedimentary strata over their beds. We are now to glance at the agencies which regulate and modify this distribution. In lakes, especially those of small extent, the modifying agencies are slight and the strata will ordinarily constitute basin-shaped deposits. But in oceans and seas there are several powerful causes, which are of great interest not only on account of the effects which they are actually producing, but because the effects are *examples* of agencies, which have in former epochs acted in a similar manner to form a large portion of the present surface of continents. They are waves, tides, currents and icebergs.

Waves.

In consequence of the indefinite and imaginative descriptions which are common of waves running "mountain high," those who are not familiar with the open ocean, seldom have correct conceptions of them. These 'mountains' rarely exceed thirty feet in height, although they have been observed in the Pacific of the height of forty feet. We were once favored with an exhibition of waves on a scale of unusual magnitude, when the height of their summits was, for the most part, not over thirty feet above the bottom of the depressions, and the highest did not exceed thirty-five feet. Although these waves were suddenly raised by a storm, which had been immediately preceded by another at right angles, in the Gulf Stream, and were of course very short and narrow, the height was less than one-tenth of the width. Enormous as are these masses, which may be a half mile or more in length, the sublimity of such a scene depends more on their motion than on their magnitude. The motion, which, as is well known, is a motion of the form and not of the substance, is often twenty miles per hour, rapidly rolling past the fleetest ships.

But since the motion is not in the substance of the water, this agency acts only at a moderate depth, and geological effects are produced only when these masses are driven on shoals and coasts. Here, on account of the resistance of the bottom, they roll up a front more and more steep until it becomes perpendicular, and being still urged on, they fall over and break with enormous force on the coast, dashing up the sides of rocky cliffs or rushing in a sheet of foam far up a sloping shore.

One of the most common effects is the wearing of loose stones, originally rough and angular, into smooth oval pebbles. On a sloping shore the loose stones are exposed to the continual friction of rolling up and down, and those of the hardest flints are usually the most perfectly rounded. On shores

where the rocks are limestone occasionally containing flint, the pebbles of flint are found to exceed in number those of the limestone, most of the latter having been entirely destroyed by the continual friction. The form will depend somewhat upon the structure of the rock, slates furnishing small much-flattened oval forms, constituting a mass of gravel or shingle. Sometimes steep shores of granite or other hard rock are covered deeply with large loose pebbles, such as furnish the paving stones for our cities, the rattling down of thousands of which after the retiring waves produces a crashing sound. of painful intensity. Storms sometimes pile up at the head of sandy beaches, out of the reach of ordinary tides, enormous ridges of pebbles. An example may be seen at Chelsea beach near Boston, where is a ridge mostly of pebbles of porphyry, two miles long, ten to fifteen feet high, and four rods wide, like a wall, between the sea and low marshes within. Blocks of stones of several tons weight are also moved in storms by the force of the waves, and a coast is modified so as to be recognized only in its outline, the minute details of the shore being entirely changed.

On coasts which are fringed with cliffs of loose materials, the waves undermine the cliffs until fragments fall down an easy prey to the next storm. If the cliffs are composed of the drift deposits, the finer materials are washed away, while the shore at its base is covered with large boulders, monuments of ruin. But if the cliffs are of solid rock, they will oppose a more effectual resistance. Yet solid rock is not impregnable, for the waves, taking up loose fragments, use them like battering rams to undermine the base of the cliff, while the agency of frost above aids in the work. If the cliffs be of limestone of unequal hardness from the intermixture of silex, peculiar and remarkable effects are produced; the siliceous fragments furnish nearly indestructible pebbles, which wear out cavities and sometimes long irregular caverns, whose sides, consisting of smooth cavities, attest the agency by which they were formed.

Oceanic Currents.

The naked rocks on the outside of Boston harbor, and the crumbling cliffs of Drift on the inner islands, shew the agency of easterly storms in the excavation of the harbor. Much of the eastern coast of England is rapidly crumbling away, and many towns are known only in history, their site now forming a part of the German ocean. In the harbor of Sherringham there was, ten years since, depth sufficient to float a frigate, where forty-eight years before there was a cliff fifty feet high with houses on it.

More or less modified and aided by *oceanic currents*, the sea is making extensive depredations on some shores and building up others.

The materials which are brought down by rivers and removed from the shore by waves are not then left to subside at once to the bottom of the sea. Oceanic currents, some perpetual and fixed in their course, and others intermittent and variable, bear the finer sediment into the deeper part of the ocean. The most remarkable and well known is the *Gulf Stream*, which flows past the eastern coast of South America, bearing the sediment of the Amazon to the north, and forming vast districts of low land between that river and the Oronoco; then spreading through the Caribbean Sea it enters the Gulf of Mexico, where, being pent up, it rushes through the straits of Florida with a velocity of four miles per hour, diminishing to three miles off Cape Hatteras, whence it takes a north-easterly course to the Banks of Newfoundland, where it is met by another current from Baffin's Bay and deflected towards Iceland, Spitsbergen, and the Northern parts of Scotland. In this great river of the ocean flow about 90,000,000,000 of cubic feet of water per minute, or 3000 times the amount discharged by the Mississippi. The polar current from Baffin's Bay is divided on meeting with the Gulf Stream, one portion being supposed to run under the latter to the south, and the other flowing on the surface between the Gulf Stream and the coast of North America. Another current of great size flows from the Antarctic ocean along the Western coast of South America. That Arctic or Antarctic currents flow beneath the surface into the equatorial regions of the Atlantic is proved by the temperature of the Caribbean Sea, which on the surface is 80°, but at the depth of 240 fathoms is 48°, only 1° warmer than at a corresponding depth within some parts of the Arctic circle. One of the under currents has been found at the equator 200 miles broad and 23° colder than the surface water.

These great currents are influenced to some extent by long storms and prevailing winds, and other less and local currents are entirely remodeled by storms.

The ocean is thus not a great lake, but a mass of broad rivers, whose size and complexity of divided, deflected, upper and under currents, present to the geologist a vast and intricate problem, whose details are yet to be solved. If the fine sediment which comes within the influence of these currents subsides at the rate of one foot per hour, it will be carried hundreds or thousands of miles, and in many cases by upper and under currents in different directions, before it will repose on the bed of the ocean in strata which are destined to be the slate rocks of some future geological epoch. Extensive shoals and long low islands occur off the coast of the Southern States which are separated from

the main land by large bodies of water, and which are probably the products of oceanic currents. Long Island once constituted several islands, which have been united into one by the action of tides and currents and waves. Off Massachusetts Bay, far out in the deep sea but west of the Gulf Stream, are dangerous shoals which have probably been formed by currents.

Oceanic currents not only distribute the sediment which is mechanically suspended, but they also aid the waves and tides in mingling throughout the ocean with great uniformity its saline ingredients, whether they are dissolved primarily by its own waters or by rivers.

Icebergs.

Icebergs are masses of fresh-water ice which are seen floating on the ocean or stranded on shoals both in the northern and southern hemispheres, and with few exceptions in latitudes above 40°.

In their *origin*, icebergs are glaciers formed in the higher latitudes all along the coasts and in the bays, in the same manner in which glaciers are formed in the Alps; (see page 43). The new Antarctic continent, which was discovered in 66° south latitude by the exploring expedition sent out by our Government, was found to be bounded continuously by icy cliffs from one hundred and fifty to two hundred feet in height, without any appearance of rocks. "No break in this icy barrier where a foot could be set on the rocks, was observable from aloft." A long range of icebergs were seen stranded in the sea, where bottom could not be reached with a line of nine hundred feet. The line of the icy barrier was only here and there pierced by deep bays, but otherwise was quite uniform. A few floating icebergs were seen with rocks and earth on them, on one of which a landing was effected and some geological specimens were obtained. One rock was five or six feet in diameter. On the iceberg was a pond of fresh water of an acre in extent. Captain Wilkes describes the icebergs which were seen near their source as distinctly stratified, resulting from successive deposits of snow, which was supposed to fall to the amount of thirty feet per year. By occasional thaws they became more compact, aided not a little by the fogs, which on one occasion formed one fourth of an inch of ice on the rigging in a few hours. The Astrolabe (of a French expedition)

"skirted for sixty miles a perfectly vertical wall of ice, elevated one hundred and twenty to one hundred and thirty feet above the waves whose surface was perfectly level. Here we have the source of the enormous level icebergs.—*Hayes.*

In other cases, especially in latitudes where the sun has sufficient power in summer to melt most of the snow, icebergs are formed chiefly in narrow valleys at the head of inlets of the sea, where the snow is sheltered from the low summer's sun, and the water flows down on it from the neighboring hills. Thus in South Georgia are formed perpendicular or overhanging cliffs of ice several hundred feet high. In Sandwich Land an intelligent navigator observed that

"the ice made from the tops of the highest hills down into the sea. In one place in particular, the sea had washed in under the ice as far as we could see, and this huge body of ice, four or five hundred feet in height on its face, and a mile or two in length, hung, not touching the beach by four or five feet, except at the sides of the mountains where it formed. The face next the sea was nearly perpendicular. * * * In Greenland the long narrow bays or fiords, like broad rivers, run far up amid the lofty mountains or table lands of the interior. The vast plains of the interior abut upon these fiords; hence the greater number are closed by a glacier, close to which the water has a depth of several hundred fathoms. Several of the inlets are now completely filled up, and at others the ice projects far out into the waves, forming a considerable promontory."—*Hayes.*

In the eastern part of Iceland is a region of 3000 square miles almost entirely covered with vast mountains of ice.

Undermined by the waves and ruptured by the frost, immense masses are occasionally detached into the sea, producing by their fall enormous waves, which loosen other masses, urging on icebergs which have stranded, and wash off rocks and the projecting portions of others. The noise made by the fall of the enormous masses of ice is compared to thunder, and by the first settlers on the Shetland Isles was mistaken for earthquakes. Most of the falling masses, however, are comparatively small fragments, and no one has seen the detachment of the larger ice islands. These are several miles in extent; navigators frequently mention them as being from five to ten miles in length. The French exploring expedition, above-mentioned, measured several which were a mile in breadth; and one was 13 miles long, with vertical walls 100 feet high. It must, therefore, have been 600 or 800 feet thick.* Another seen by the same expedition was 225 feet high, which would give a depth below the surface of 1400 to 1800 feet. Capt. Ross saw several aground in Baffin's Bay, in water which was 1500 feet deep.

The *motions* of icebergs are of great importance not merely for the effects produced at the present time, but for their bearing on the theories of the Drift deposits. The most ordinary motion is a uniform slow progress from higher to warmer latitudes irrespective of wind and waves. This motion is the effect of those under currents with which their enormous depth in the water brings

*Ice floats with one-ninth of its bulk above the surface. Making allowance for any want of compactness, and especially for a greater breadth of the base, the depth of an iceberg may be reckoned at between 6 and 8 times the height.

them in contact. Immense numbers of them are from this cause often seen to the east of Newfoundland, where floating from the north they at length, in latitude 43°, come into the warm Gulf Stream, which there has an eastern course, and urged on by the current beneath the Gulf Stream they float in a direction across the latter, usually disappearing, however, before they reach its southern side in latitude 36°. Many of them get aground on the Grand Banks before they reach the Gulf Stream.

One of the most extraordinary examples of size and motion was an iceberg seen by the British steamer, the Acadia, on the 16th May, 1842, latitude 46°, longitude 47°, among 100 others, and which was 400 to 500 feet high, and consequently about 3000 feet deep in the water. It must therefore, have nearly equalled from the base to the summit, the highest peaks of the Green mountains. Having a remarkable resemblance to St Paul's Cathedral in London, it was named St. Paul's. But the most extraordinary part of the narrative is that "on the 6th June the same object was seen, and the immediate exclamation on board was, there is our old friend St. Paul's. In the interim between the two views, the iceberg had drifted about 70 miles." This slow motion, 70 miles in twenty-one days, is worthy of notice. The maximum force of the polar current off Newfoundland is two miles per hour, and although liable to be retarded it can hardly be supposed to be reduced to one-seventh of a mile per hour for 21 days. It is not improbable that this enormous iceberg was retarded by ploughing the bottom of the sea in some parts of its course.

In the southern hemisphere currents from the polar regions in the same manner float the icebergs into warmer latitudes, occasionally as far as the latitude of the Cape of Good Hope.

In their progress into regions of less intense cold, the structure of icebergs changes; the stratification disappears and the whole becomes a compact mass of translucent blue ice, and the surface presents all conceivable forms, which the imagination easily converts into a city with its spires, domes and battlements.

Another motion is that of a violent heaving and rolling of the mass when aground. Capt. Couthuoy in August, 1827, saw one stranded on the Grand Bank in about 500 feet of water, around which to the distance of one-fourth of a mile, the water was full of mud stirred up by the violent rolling of the mass.

Icebergs floating into warmer water and melting more rapidly on some portion than others sometimes change their centre of gravity, and the enormous mass is seen to topple over, producing great commotion in the water.

The *dissolution* of icebergs is sometimes effected by a violent explosion, rending the whole into fragments, which soon disappear. Several cases of this kind are recorded and are supposed to be owing to the expansion of bodies of air confined within the ice at a temperature much below the freezing point, and when the temperature of the ice rises up to this point, the air must expand and the ice explode. But the ordinary process is that of melting in warmer waters, and here we have the most important feature in the modern history of icebergs as illustrative of the past.* It is obvious that whatever foreign materials, rocks and earth, may be borne along with them, will be dropped in their path on the bed of the ocean. It is, however, rarely that icebergs at a great distance from their orignal source are seen thus loaded. The one above mentioned as seen by Capt. Couthuoy was thus loaded, and a few other cases are recorded. But they are rare, and many navigators have seen thousands of icebergs no one of which bore along any foreign materials. On the other hand such materials have been seen on them before and soon after they were detached. It is not improbable, although in many cases a mass of rocks and earth may be a nucleus as affirmed by some, around which the ice accumulated, that, since these materials must rest on some base, they cannot occupy the interior of the ice, and therefore are lost soon after the icebergs are detached. Whatever materials adhere from any cause to their sides will be dropped near their source.

The two great powers which we have thus considered, fire and water, are to some extent in their geological effects, as they are in their nature, antagonist forces. Running water is constantly removing the land by slow degrees from higher to lower levels, and into the sea, while volcanoes are raising, from within the crust of the earth, to a greater or less height their floods of melted rocks. Earthquakes are also engaged in lifting whole countries by violent shocks, while some unknown power, perhaps *the plication of the crust of the earth*, is gradually effecting the same result. As, however, water in some cases reverses its usual mode of operation, and in springs raises its soluble contents from deep places and deposits them on the surface of the ground, so on the other hand, the igneous agencies not unfrequently reverse the more common process of elevation, and we see earthquakes swallowing down large portions of land. It is obvious, that rivers carry into the sea an amount of sediment greatly exceeding the eruptions of volcanoes, and if the elevatory effects of earthquakes did not exceed those of depression, the general tendency would be to reduce the earth to a uniform level. But if, as is stated, the great earthquake of Chile raised an extent of 100,000 square miles three feet in height, here was the amount of two and three-fourths millions of millions of cubic feet raised at once above the sea level. Similar elevations may occur in places which are at a distance from the sea, and therefore shew no obvious proof of elevation.

* Not that we adopt the iceberg theory of Drift exclusively; see the subject of Drift.

The great problem therefore of the general tendency of existing forces is as complicated as it is grand in its numerous and conflicting elements.

There are some other physical agencies, of more of less importance, which we have not introduced in our classification, because they are of limited extent. Rocks are sometimes split by lightning, and terrestrial magnetism or rather galvanism has been supposed to exert an important influence, especially in metallic veins. In districts of fine sand, winds exert an important agency in their distribution. It is well known that many of the remains of the ancient Egyptian architecture are more or less buried in impalpable dust. We are familiar with the accounts of caravans on the great deserts of northern Africa overtaken and buried beneath blown sand, and in Europe some villages have been destroyed by drifting sands. A few examples of such sands in this country are known, but have not attracted much attention.

ORGANIC AGENCIES.

The nature of organic agencies is of great interest to the geologist because they show how extensive rock formations are and have been formed, as well as for the indispensable aid which a knowledge of this subject furnishes in tracing out the history of the extinct species of animals and plants, which are found in a fossil state.

A minute practical knowledge of the natural history and anatomy of the numerous tribes of animals and plants is necessary to this end, but since it requires the devotion of a life time to attain this knowledge in any one of the numerous sciences which treat of these subjects, the geologist, after becoming familiar with their outlines, contents himself with depending on the aid of zoologists and botanists, in determining the character and habits of extinct species. It is indeed fortunate for him if he has been familiar with some one branch of these sciences.

As indispensable even to the mere reader of geology, we subjoin a brief outline of the *classification* of the animal kingdom. About 150,000 species of animals (of which two-thirds are insects,) and 100,000 species of plants are known to naturalists. The object of classification is not merely to aid the memory in the knowledge of such a multitude of objects, but also to exhibit the affinities between them, by which they are associated in groups whose members have certain fundamental characters common among themselves and distinctive from all others.

The first step in classification therefore is to determine the limits of *species*, which include those individuals, and those only, whose differences may be accounted for by the effect of climate, food, &c. which may therefore have descended from one common stock like the human species, and which are capable of propagating their kind. *Genera* are composed of those species which most nearly resemble each other in their anatomical structure, and which appear as if they were made after one pattern with modifications peculiar to each, regard being had solely to their conformity to this pattern, and not to any arbitrary rules. The number of the species in the several genera varies from one to several hundred. The genera are next in the same manner associated in *families*, the families in *orders*, the orders in *classes*, and the classes in general *divisions*.

This plan may be thus exhibited :

General divisions.	Classes.	Orders.	Families.	Genera.	Species.
A	A	A	I	a	1, 2, 3
				b	4, 5
			II	c	6, 7
		B	III	d	8, 9
			IV	e	10, 11
				f	12
	B	C	V	g	13, 14
				h	15, 16
		D	VI	k	17, 18, 19
			VII	l	20, 21
				m	22

Each of the groups has a distinct name, and the species in their several genera are named on the same plan by which the members of a human family are named ; that is, the name of a genus to which a species belongs is taken as the surname and an additional name is given to distinguish it from the other species in the same genus, while the generic name distinguishes it from any in other genera. Thus the genus to which the dog and wolf

belong is *canis*, and the name of the dog, *canis familiaris ;* and of the common wolf, *canis lupus.*

The animal kingdom is divided into the following five grand divisions, which are characterised primarily by the nervous system, which is the most important and distinguishing feature of animals.

1. VERTEBRATA. This division comprises the highest orders of animals, with man at the head. The nervous system consists of a *brain* and *spinal cord* from which branches are given off ramifying indefinitely through the body. There is also a *sympathetic system* of nerves, which are the source of the involuntary motions, as the beating of the heart, and which originate from several centres in the body. The vertebrata also are characterised by the possession of a *skeleton*, consisting of bones, which, unlike the hard parts of other animals, grow and are continually nourished by the circulation of the blood. The organs of the five senses are manifest in all of them, and four of the senses have a distinct apparatus placed in the cavities of the face. Examples of this division are the warm blooded quadrupeds, birds, reptiles and fishes. The name is derived from the vertebræ or spine. A knowledge of the classes and orders of this division, with many of their details, is indispensable to much progress in geology, since their fossil remains, although they are far less common than shells in the strata, lead to very interesting and important conclusions respecting the condition of the surface of the earth during the period of their existence.

The ARTICULATA are distinguished by a nervous system, which consists of nervous centres arranged in two parallel lines along the length of the body, the anterior one in the head being the larger. These centres send out nerves and may be regarded as so many brains, the number of which is inversely proportioned to the activity and intelligence of the animals. In this division we find an external frame work of jointed rings. Insects, spiders, crabs, barnacles, and worms are examples of this division. The name is derived from *articulus*, a joint. Of the classes of this division, the species of insects are by far the most numerous, constituting, as before mentioned, two-thirds of the animal kingdom. The astonishing number of the individuals also, their direct influence on vegetation, and their direct or indirect agency on other animals, render the study of them one of the most important branches of Zoology. But so few relics of them exist in a fossil state, that this study is of little importance to geology.

In the MOLLUSCA the nervous system consists of several irregularly scattered masses, of which one over the throat is the larger. Most of them are covered with shells. Examples are clams, oysters, snails, &c. The name is derived from *mollis*, soft. The study of the *shells* of these animals gives rise to the science of *conchology*, a subject which is of the highest importance to the geologist: for the great majority of the fossils, by means of which the age of the geological formations is ascertained, are shells. But since the question of the economical resources of the formations is intimately connected with their age, the study of shells becomes therefore indirectly of great economical importance. Thus inspection of the shells in the rocks near Lake Champlain shews the geologist, that the expectation of finding coal in them, or in any rocks associated with them, is utterly futile. Those who value a knowledge of the works of nature only from mercenary considerations, and who suppose that the study of conchology is useless, are therefore condemned by their own standard. Univalve or bivalve shells are those which are composed, the former of one, and the latter of two principal pieces. Of the univalve shells, some are divided by partitions into several chambers, which are air-tight and serve as a float to the animal. At the present time these are not numerous, but in former geological epochs, they were very abundant. They belong to the class of cephalopods, (see table on page 57). The multivalve shells, (those which are composed of more than two pieces), for the most part, do not however belong to this division of animals, but to the cirrhopods, a class of articulated animals.

The NEMATONEURA have the nervous system less fully developed, consisting of filaments of nervous matter, with indistinct masses or centres in a few of them. Examples are sea stars, many intestinal worms, and some animalcules, and a few minute marine animals allied to the coral animals. The name is derived from the Greek words νημα and νευρα, thread nerve.

In the ACRITA no nervous system has been recognised, and their bodies consist of fleshy or gelatinous masses, without distinct organs of digestion or motion. They may be cut in pieces with impunity, each part becoming an entire animal, and they naturally increase by spontaneous division, as well as by offshoots and by eggs. Examples are the animals which secrete the well known coral structures, some animalcules, sun fishes, sponges, &c. The name is derived from two Greek words α and κρινω, indiscernable, because no nerves have yet been found in them.

Although a knowledge of Zoology and Botany, in detail, especially of the former, is indispensable to the practical geologist, and is of great importance to the mere reader of geology, we do not consider it proper to insert here more than the following synopsis of the classes and orders of the vertebrata, of the classes of the other divisions, and of the classes of plants.

CLASSES OF THE ANIMAL KINGDOM.

				Classes.	*Examples.*
VERTEBRATA.	Viviparous, suckling their young.	Respiration aerial, with lungs.	Warm blood.	*Mammalia.*	See the orders of vertebrata, on next page.
	Oviparous.			*Birds.*	
			Cold blood.	*Reptiles.*	
		Respiration aquatic, with gills.		*Fishes.*	
ARTICULATA.	White blood.	Terrestrial.	With 6 legs.	*Insects.*	Beetles. Flies.
			24 or more legs.	*Myriapods.*	Centipedes.
			8 legs.	*Arachnidans.*	Spiders. Scorpions.
		Aquatic.	10 or 14 legs.	*Crustaceans.*	Lobsters. Crabs.
			No legs.	*Cirrhopods.*	Barnacles.
	Red blood.	Aquatic or Terrestrial.		*Annelidans.*	Earthworms. Leeches.
MOLLUSCA.	With a distinct head.	Naked, or with a univalve shell.		*Cephalopods.*	Nautilus. Cuttlefish.
				Pteropods.	Hyalaea.
				Gasteropods.	Slugs. Snails. Cowries.
	Without a distinct head.	With a bivalve shell.		*Branchiopods.*	Terebratula.
				Conchifers.	Clams. Oysters.
				Tunicata.	Ascidia.
NEMATONEURA.	Marine.			*Echinodermata.*	Sea stars.
	Parasitic and Aquatic.			*Coelelmintha.*	Cavitary intestinal worms.
				Epizoa.	Parasites on fishes and on crabs.
	Aquatic.			*Rotifera.*	Wheel animalcules.
	Marine.			*Bryozoa.*	Flustra.
ACRITA.	Parasitic.			*Sterelmintha.*	Parenchymatous intestinal worms.
	Marine.			*Acalephæ.*	Sunfish, and Portuguese man-of-war.
	Aquatic.			*Polygastrica.*	Animalcules with many stomachs.
	Marine.			*Polypi.*	Animals which form corals.
				Porifera.	Sponges.

ORDERS OF VERTEBRATA.

				Orders.	Examples.
MAMMALIA.	With nails on the fingers and toes.	Two hands.		*Bimana.*	Man.
		Four hands.		*Quadrumana.*	Monkeys.
		With all kinds of teeth, viz. incisors, canine and molar.		*Carnaria.*	Cats. Tigers.
		Wanting canines		*Rodentia.*	Squirrels. Rabbits.
		Incisors wanting, or without teeth.		*Edentata.*	Sloths. Anteaters.
		With mammary pouches for the young.		*Marsupialia.*	Opossums.
	With hoofs.	Thick skinned, not ruminant.		*Pachydermata.*	Horses. Elephants.
		Ruminant.		*Ruminantia.*	Oxen. Deer.
	With paddles.	With the form of fishes.		*Cetacea.*	Whales.
BIRDS.	Terrestrial.	Talons strong.		Birds of prey, *Rapaces.*	Eagles. Hawks. Owls.
		Toes feeble.		Migratory, *Passerinae.*	Sparrows. Swallows.
				Climbers, *Scansoriae.*	Woodpeckers. Parrots.
				Gallinaceae.	Turkeys. Quails.
	Aquatic.	Legs long.		Waders, *Grallatoriae.*	Herons. Ostriches.
		Web-footed.		Swimmers, *Palmipedes.*	Gulls. Ducks.
REPTILES.	Respiration aërial always.	Four extremities with nails. Covered with scales.	With the skeleton expanded in a shell.	*Chelonians.*	Tortoises.
			Without a shell.	*Saurians.*	Lizards. Alligators.
		No extremities.		*Ophidians.*	Snakes.
	At first aquatic, with gills; when mature, respiration aerial.	Four extremities without nails. Naked		*Batrachians.*	Frogs, &c. Salamanders.
FISHES.	Covered with plates or tubercles, large or small, of enamel.			*Placoidians.*	Sharks.
	With angular scales, each with a coat of enamel.			*Ganoidians.*	Sturgeons. Pikes.
	Scales jagged.	Without enamel.		*Ctenoidians.*	Perches.
	Scales with margin entire.			*Cycloidians.*	Salmons. Herrings.

The leading characters of the classes of plants may be analytically expressed in the following manner:

				CLASSES.	EXAMPLES.
PLANTS.	Furnished with flowers and	producing seeds in a pericarp.*	Embryo dicotyledonous;† growth exogenous.‡	Exogens.	Oaks. Maples.
			Embryo monocotyledonous; growth endogenous.‡	Endogens.	Grasses. Palms.
		producing naked seeds.*		Gymnosperms.	Pines.
		producing spores § instead of seeds.		Sporogens.	Rafflesia.
	Destitute of flowers and producing spores instead of seeds;	but with regular stems growing from the apex, and furnished with leaves.		Acrogens.	Ferns. Mosses.
		and with no distinction of stem and leaves, or regular axis of growth.		Thallogens.	Lichens. Seaweed.

* The envelope of a seed; it is the hull on grain, the shell of nuts. In the cones of pine trees the seeds are between but not enveloped by the parts of the cone.

† The rudiments in the seed of the first pair of leaves are called cotyledons which are two in beans, peas, the seeds of the trees of this climate &c. and such plants therefore are said to be dicotyledonous. In corn, asparagus seed, cocoa nuts &c. there is a single rudiment of a leaf, and such plants are therefore called monocotyledonous.

‡ Some plants grow externally by the addition of layers between the bark and wood and are therefore called exogenous. Such are all the trees of this climate. Others have no proper bark, and grow by additions within, like the corn stalk, asparagus, grasses and palm trees. Such are therefore called endogenous.

§ Differing from seeds in not containing an embryo, but producing root and stem from any portion indifferently; they are usually very minute; thus the dust of the puff-ball consists of spores.

We are at first to consider the agency of animals and of plants in the formation of rocks, and various deposits. It is a circumstance truly remarkable that animals the most minute, nearly or quite invisible to the naked eye, and among the lowest in the scale of beings, are those only, which are forming solid rocks or deposits of sufficient magnitude to engage the attention of the geologist.

Corals.

The most important organic agency undoubtedly is to be found in these well known structures. The animals which construct them belong to the class *polypi*, or polypes, and consist of a homogenous fleshy bag, open at one extremity, which is fringed with tubercles. With the exception of the first few days of their existence, they are immovably attached to some basis and derive their support from animalcules or particles of organic matter which come within their reach. With such an extreme simplicity of organization and habits, they of course have a low rank in the animal kingdom, and nothing can therefore be more absurd than the common error of calling them insects; for insects, although minute, are extremely complicated in their organs and vivacious in their movements. In these respects the polypi and insects are at the opposite extremes of the animal kingdom. They are also sometimes called animalcules, improperly, because this name is appropriated to two other classes of animals, (see page 57), which have a very different character. The polypi are however very minute, seldom exceeding the size of a pea, more frequently less than a pin head, or are even invisible. They have the remarkable property of living united in one common mass, so that whatever is swallowed and digested by each contributes to the nourishment of the community by a common circulation. The solid coral is not a structure voluntarily made by them, but a secretion in which they have as little design as the oyster in secreting his shell, or a quadruped in the growth of its bones. In the minute pores of this solid secretion of carbonate of lime are the polypi themselves, sometimes expanding and covering its surface with their gelatinous slimy but richly colored bodies, or when alarmed entirely withdrawn into the cavities.

One interesting result of the recent Exploring Expedition, has been the knowledge of the temperature requisite for the existence of these rock-building animals. In seas whose temperature is below 75° they do not flourish, and hence along the western coast of South America, where the water is cooled by an antarctic current, coral reefs do not exist, while in the same latitude on the eastern coast they are very extensive. Nor do they build at great depths as was once supposed, but only in water not exceeding a few fathoms. Most of the soundings in tropical seas indicate a temperatare far too low for their existence. Islands in warm seas are generally girt with coral reefs, through which are occasional openings, especially opposite harbors into which some small stream of fresh water enters. If now such an island should subside beneath the waters very slowly, so that the coral reef should be built up to the surface of the water as fast as the land beneath should sink, the result at length would be a circular coral reef with a lagoon of smooth water in the middle. Such reefs, with a diameter from one to thirty miles, are common in the Pacific, and were formerly supposed to be on the summits of volcanoes, but in many cases the theory above stated is quite as probable.

These reefs are very numerous in many parts of the Indian and Pacific oceans, and constitute one of the greatest dangers of navi-

gation. Notwithstanding the minuteness of the animals, reefs of vast extent are described.

"On the eastern coast of New Holland, is a reef 350 miles long. Disappointment Islands and Duff's Group are connected by 500 miles of coral reefs, over which the natives can travel from one island to another. Between New Holland and New Guinea is a line of reefs 700 miles long, interrupted in no place by channels more than thirty miles wide. A chain of islets 480 geographical miles long, has long been known by the name of the Maldivas. Some groups in the Pacific, known as the Dangerous Archipelago, are from 1100 to 1200 miles long, and from 300 to 400 miles broad."—*Hk.*

It has been supposed on account of the existence of shells nearly buried in the substance of corals, while the mollusca were yet living, that the growth of corals was rapid. But Mr. Couthuoy (zoologist of the Exploring Expedition) finds that in such cases the animals in the shells have excavated the cavity in the reef. On the other hand the growth is so slow as not to present any very satisfactory data for determining its rate. Thus the most stupendous effects are produced not only by the feeblest agents, but by an imperceptible progress.

Animalcules.

The least of all the animal kingdom rank next to the polypi in importance as geological agents. Forms from the simple spherical shape to the most grotesque which can be imagined exist among them. Some are visible to the naked eye, but others are only one twenty-four thousandth of an inch in diameter, and a number equal to the entire population ofthe globe might sport freely in a single drop of water; yet their remains constitute strata many feet in thickness. Animalcules were once supposed to be mere animated particles of matter without structure, but they are now, owing to the perfection of microscopes, and to the patience and skill of naturalists, well known to have quite a complete organization. Many of them live in a compound state like the polypi above mentioned. Although their vitality is not destroyed by remaining in the state of dry dust for years, yet they are active only in liquids; they are most common in stagnant waters, but some live in pure water, and few liquids, except such as are poisonous,are entirely free from them. But the character of the most interest in this connection, is the *shell*, with which a majority of the species are furnished. Fragile as such shells might be supposed to be, yet as they consist of silex they retain their original form and structure for indefinite periods of time. A number of beds of siliceous marl, an impalpable pulverulent deposit, found usually beneath the beds of peat or muck in Massachusetts and other places, have been found to be chiefly composed of these shells to the depth of several feet.

The vast quantiy of these deposits is less astonishing when we consider the fecundity of animalcnles, some of which will have millions of descendants in a few days. Thus one individual of of the large species, Hydatina senta, in twelve days may produce 16,000,000, and another in four days 170,000,000,000; and Ehrenberg, to whom science is indebted more than to all others on this subject, affirms that if the price of tripoli (rotten stone or polishing powder, which is composed of their shells) should rise materially, he could raise animalcules, and collect the shells, and sell them at a profit for polishing powder. He has actually obtained several pounds by rearing the animalcules. We may have occasion to notice again deposits of these shells in Germany of the thickness of fourteen and twenty-eight feet, and to describe some as existing in this State.

On account of the great extent of siliceous deposits known to have originated from this source, some geologists have been inclined to believe that most of the siliceous strata in the crust of the earth once constituted the shells of animalcules.

Other species of animalcules have shells composed of iron rust, and much of the iron scum, which may be seen floating on water, consists of animalcules.

Nor are animalcules limited to fresh water deposits, but many exist in the sea, and fossil species abound in some marine deposits, as in the chalk of England.

Another source in the animal kingdom of rocky strata is to be found in the vast quantities of the shells of mollusca and of the crustaceous coverings of other marine animals, which abound in some parts of the tropical seas. In such regions the sand of beaches is often seen to be composed of the comminuted calcareous fragments. So in the ancient Palaeozoic rocks of Lake Champlain, we shall find entire ledges composed of the comminuted fragments of corals and shells. It is probable that many beds of crystalline marble were originally composed of such fragments, and have been subsequently altered by igneous agency.

Plants are well known to form deposits of vegetable matter. From their complete decay results vegetable mould, the particular consideration of which will belong to agricultural geology. While many quickly perish, others are more enduring, and form accumulations of muck, peat and drift wood. Peat results chiefly from the partial decay of mosses, especially Sphagnum, which constantly grows as the older portions decay. Since however in hot climates the decay of plants is rapid and complete, when exposed to atmospheric agency, beds of peat are found only in cold countries.

Immense rafts of drift wood are well known to accumulate in the lower part of the rivers of this continent.

"In consequence of some obstruction in the Atchafalaya, supposed to have been formerly the bed of Red River but now an arm of the Mississippi, a raft accumulated in 38 years, which in 1816 was 10 miles long, 220 yards wide, and eight feet thick. Although floating it is covered with soil and living plants.

"Similar rafts occur on the Red River, and one on the Washita concealed the surface for 50 miles, and supported a growth of trees. At the mouth of the Mississippi alternations of drift wood and mud extend over hundreds of square leagues."—*Hk.*

In a few cases, as in Maine and Louisiana, the process by which drift wood may be converted into coal has been seen in its incipient stages. Facts of this kind are of great interest as illustrating the origin of the immense beds of coal in the carboniferous formations.

We are now to consider organic agency as illustrating the *origin* of those *fossil bodies*, to which geology is mainly indebted both for its great principles and for its most interesting details.

Human agency has exerted a powerful effect, especially in temperate climates, both in modifying other agencies and in depositing in the earth the relics of man himself.

"The human race produce geological changes in several modes: 1. By the destruction of vast numbers of animals and plants to make room for themselves. 2. By aiding in the wide distribution of many animals and plants, that accompany man in his migrations. 3. By destroying the equilibrium between conflicting species of animals and plants, and thus enabling some species to predominate at the expense of others. 4. By altering the climate of large countries by means of cultivation. 5. By resisting the encroachments of rivers and the ocean. 6. By helping to degrade the higher parts of the earth's surface. 7. By contributing peculiar fossil relics to the alluvial depositions now going on, on the land and in the sea: such as the skeletons of his own frame, the various productions of his art, numerous gold and silver coins, jewelry, cannon balls, &c. that sink to the bottom of the ocean in shipwrecks, or become otherwise entombed." (Hk.)

"When we reflect on the number of curious monuments consigned to the bed of the ocean, in the course of every naval war from the earliest times, our conceptions are greatly raised respecting the multiplicity of lasting memorials which man is leaving of his labors. During our last struggle with France, thirty-two of our ships of the line went to the bottom in the space of twenty-two years, besides seven 50-gun ships, eighty-six frigates and a multitude of smaller vessels. The navies of the other European powers, France, Holland, Spain and Denmark, were almost annihilated during the same period, so that the aggregate of their losses must have many times exceeded that of Great Britain. In every one of these ships were batteries of cannon constructed of iron or brass, whereof a great number had the dates and places of their manufacture inscribed upon them in letters cast in metal. In each there were coins of copper, silver, and often many of gold, capable of serving as valuable historical monuments; in each were an infinite variety of instruments of the arts of war and peace; many formed of materials such as glass and earthern ware, capable of lasting for indefinite ages when once removed from the mechanical action of the waves, and buried under a mass of matter which may exclude the corroding action of the water.

"But let it not be imagined that the fury of war is more conducive than the peaceful spirit of commercial enterprise to the accumulation of wrecked vessels in the bed of the sea. From an examination of Lloyd's lists, from the year 1793 to the commencement of 1829, Captain W. H. Smyth ascertained that the number of *British vessels* alone lost during that period amounted on an average to no less than one and a half *daily;* an extent of loss which would hardly have been anticipated, although Moreau's Tables shew that the number of merchant vessels employed at one time, in the navigation of England and Scotland, amounted to about twenty thousand, having one with another a mean burthen of 120 tons. Mr. J. L. Prevost, also informs me that, on inspecting Lloyd's lists for the years of 1829, 1830, and 1831, he finds that no less than nineteen hundred and fifty-three were lost in those three years, their average tonnage being above 150 tons, or in all nearly 300,000 tons, being at the enormous rate of 100,000 tons annually of the merchant vessels of our nation only. This increased loss arises, I presume, from increasing activity in commerce.

"Out of five hundred and fifty ships of the royal navy lost to the country during the period above mentioned, only one hundred and sixty were taken or destroyed by the enemy, the rest having either stranded or foundered or having been burnt by accident; a striking proof that the dangers of naval warfare, however great, may be far exceeded by the storm, the shoal, the lee-shore, and all the other perils of the deep.

"Millions of silver dollars and other coins have been sometimes submerged in a single ship and on these, when they happen to be enveloped in a matrix capable of protecting them from chemical changes, much information of historical interest will remain inscribed, and endure for periods as indefinite as have the delicate markings of zoophytes or lapidified plants, in some of the ancient secondary rocks. In almost every large ship, moreover, there are some precious stones set in seals and other articles of use and ornament composed of the hardest substances in nature, on which letters and various images are carved—engravings which they may retain when included in subaqueous strata, as long as a crystal preserves its natural form.

"It was therefore a splendid boast, that the deeds of the English chivalry at Agincourt made Henry's chronicle—as rich with praise

As is the oose and bottom of the deep
With sunken wreck and sunless treasures;

for it is probable that a great number of monuments of the skill and industry of man will, in the course of ages, be collected in the bed of the ocean, than will exist at any time on the surface of the continents." (Lyell.)

Human bones also are as durable as those of other animals. Cuvier says that

"In ancient fields of cattle the bones of men have suffered as little decomposition as those of horses which were buried in the same grave."

Human bones have been found in a fossil state, and even in solid rocks. The most remarkable instance is that of the skeleton found in a fragmentary rock in Gaudaloupe. But as this rock is daily increasing by the uniting of minute fragments of shells and corals with a calcareous cement, no remote antiquity can be ascribed to these remains. In short *all* the remains of man are limited to deposits which are subsequent to the drift, the latest of all the geological formations, in accordance with the sacred scriptures, which assume a period of about six thousand years for the past existence of man and of the animals associated

with him, but do not limit the period of the antiquity of the earth itself.

The proportion of the various tribes of animals and plants which are found in a fossil state must depend not only on their number, but on the facility with which they may be preserved. It becomes therefore of great importance to consider this subject, in order to avoid erroneous conclusions respecting the Fauna and Flora of former epochs. Thus two-thirds of all the known species of organic remains are shells, but it is not to be inferred that molluscs constituted two-thirds of all the organic beings in existence. The nature and process of petrifaction, the circumstances requisite for preservation, and the durability of the parts, are the principal elements of this question.

Petrifaction consists in the substitution of particles of mineral matter in the place of the particles of vegetable or animal matter, and consequently preserves the structure of the original body. In some cases this process is known to take place at the present time, as when bones are enveloped in clay containing sulphuret of iron. Sticks, nuts, &c. in a place where bog iron ore is accumulating, are found to have been converted into ore, probably within a few years. Leaves have been artificially baked in clay and found to resemble ancient petrifactions. But little, however, is known of the *process*, for the chemical conditions favorable to it are more likely to exist under a pressure of superincumbent materials and excluded from the air.

A large portion of fossils, however, have been preserved without petrifaction, and it is therefore of more consequence to consider what circumstances are favorable to the preservation either of the substance or of the form of organic bodies. In general it is essential that the body should be buried either by aqueous or other agencies. In a few instances bodies have been preserved without the agency of water. Thus bodies of men, and remains of birds and eggs have been found buried in guano; and the moving sands of deserts bury various objects, which may be preserved indefinitely. Animals are often buried in caves and fissures by inundations, of which numerous examples have been found in Europe. Peat bogs also preserve the bodies of animals which are mired in them. Peat also accumulates over and preserves prostrate forests. The only vestiges of the forests described by Julius Cæsar along the great Roman Road in Britain are the ruined trunks of trees in peat. In frigid climates animals are sometimes entombed for ages in ice.

The ejections of volcanoes as we have seen, may bury even entire cities, and various organic bodies may be preserved in the same manner.

Floods and storms often bury immense numbers of organic beings. In 1787 on the coast of Coromandel, there was a flood occasioned by a hurricane which drove the waters of the sea inland 20 miles. This flood covered the country with mud, in which were the carcasses of 10,000 inhabitants and 100,000 cattle. When, however, the bodies are buried permanently beneath the water, the probability of their preservation is much greater, as when in 1780 an earthquake wave rushed over the city Savanna la Mar in Jamaica, and in an instant swept away the whole town, leaving not a vestige of man, beast or habitation on the surface.

But the most efficient agents are the floods of rivers, by which plants and animals are borne into deep water and often into the sea and permanently submerged. In these cases the carcases may be buried at once beneath a heavy mass of sand and stones, or being merely drowned and subsequently decaying, only their harder parts will be preserved. Even marine animals are often destroyed by the mass of materials swept down in floods.

"We are informed by Humboldt, that during the periodical swellings of the large rivers in South America great numbers of quadrupeds are annually drowned. Of the wild horses, for example, which graze in immense troops in the savannah, thousands are said to perish when the river Apure is swollen, before they have time to reach the rising ground of the Llanos. The mares, during the season of high water, may be seen, with their colts, swimming about and feeding on grass, of which the top alone waves above the waters." * * * "In Scotland, in August, 1829, a fertile district on the east coast became a scene of dreadful desolation, and a vast number of animals and plants were washed from the land, and found scattered around the mouths of the principal rivers. An eye-witness thus describes the scene which presented itself at the mouth of the Spey in Morayshire:—'For several miles along the beach crowds were employed in endeavoring to save the wood and other wreck with which the heavy rolling tide was loaded; whilst the margin of the sea was strewed with the carcasses of domestic animals, and with millions of dead hares and rabbits.'"—*Lyell.*

The solid parts of marine animals, as bones of fishes, and the shells of molluscs, of crustacea, and of echinodermata are of course often at the death of the animal in places favorable for preservation, or are swept into such places. Thus to the east of the Faroe Islands a bed of sand and mud full of broken and entire shells has been traced for 20 miles; and for the space of three and a half miles in length the mud is so full of fish bones, that the sounding lead is seldom drawn up without some vertebræ attached. Between Gibraltar and Ceuta fragments of shells have been found on a gravelly bottom at the depth of 4800 feet, carried thither by a current. Fishes are also buried by sub-marine eruptions of lava or mud.

The *durability* of parts of the bodies of the various tribes of animals and plants differs extremely, and is found to correspond

to a considerable extent with the relative quantity of their remains which have been found in a fossil state. It is therefore important to consider this subject a little in detail.

If *vertebrated* animals are buried so deep beneath a mass of sand or mud, that their putrefying bodies cannot rise to the surface, their skeletons will be preserved entire. If, however, they are not thus buried, they will soon after the commencement of putrefaction, from the formation of gases, become lighter than the water and float on the surface; decomposition will be more rapid, and the bones will fall scattered to the bottom, and be gradually covered by the deposits of mud or sand which may be going on. Birds, however, are always buoyed up by their feathers and hence only scattered bones are likely to be preserved. Their bones also being tubular are more likely to be crushed than those of other vertebrata. The skeletons of some fishes, as the sharks, being cartilaginous are more subject to decay, but their teeth being very hard will be preserved. Accordingly the bones of birds are extremely rare, and while the skeletons of many kinds of fish are common, it is seldom that any thing more than the teeth of sharks are found. Birds, however, frequently leave their tracks in fine sand and mud to be buried by additional layers of sediment, and although little search has been made by laying open strata on the banks of rivers and on the shores of the sea, a number of examples have been found. It will be seen in the sequel that the tracks of birds are far more frequently found in the rocks than are any other relics of them.

Of the *articulata*, insects, although far more numerous than any or all other classes except the animalcules, are very rarely preserved. The naturalist in searching for objects of Natural History, rarely finds dead insects. Multitudes of them with a ferocious activity prey upon each other. On the water or on the land they are the favorite food of numerous tribes of vertebrata; bats, lizards, frogs, fishes and birds devour myriads. Permeated by the innumerable air tubes of respiration, they after death speedily decay by atmospheric agency. Being from the same cause lighter than the water they are rarely buried, but like birds float on the surface, without however eventually dropping any solid parts, but either decaying or becoming the prey of fishes. Rarely therefore either in the recent or older rocks are their remains found. Yet as it would obviously be incorrect to infer from the paucity of their remains in alluvial deposits, that few exist at the present day, so it would be equally erroneous to infer positively that they were not more numerous in former periods than the number of their remains would indicate. The remains which have been formed are either those of insects that frequent water, and are therefore, more likely to be buried in the mud, or the elytra of beetles, which are the most indestructible parts.

Of the myriapods the same remark may be made: covered with crustaceous rings of about the consistence of the harder parts of beetles, they are about equally durable and are found about as frequently in their haunts. Unaccustomed to frequent wet places, they are not likely to be entombed.

Of the arachnida a majority are extremely frail, but a few, especially the scorpions, are as durable as any of the beetles, being covered with a hard crust, and a few have been found in a fossil state. The most durable species of this class are however not aquatic.

Most of the crustaceans are covered with a crust much harder than any of the preceding articulata, and parts of some of them have the solidity of bones. They are mostly marine: some, especially of the minute species, inhabit fresh water, and a few are capable of living on dry land. They are, therefore, much more frequently preserved.

Of the cirrhopods many are covered with true shells of solid carbonate of lime, and as they are marine there can be no reason why they should not be preserved in as large proportion as any tribes of organic beings. From their deficiency in the geological formations, it may quite safely be inferred that the class is of comparatively recent introduction.

Annelidans are less durable than the myriapods which they resemble in their general form. But many of them are aquatic, and, having the habit of burying themselves in the mud or sand, are not very unlikely to be preserved, notwithstanding the exceeding frailty of their structure. It is quite remarkable that the oldest animals, yet described as existing in any geological formation, are marine worms with very slender and perishable bodies. Their remains, although distinct, usually resemble faint impressions. The tracks of earth-worms, which are so abundantly seen immediately after a heavy rain has driven them out of their holes, are often in a situation to be soon covered with a layer of mud, and are quite likely to be preserved. Impressions on some of the solid rocks probably have a similar origin.

All the classes of *mollusca*, except the Tunicata, consist either wholly or to a great extent of species, which are furnished with solid or calcareous shells, and have mostly aquatic habits. They exist in great numbers in places favorable for their preservation, and not a few live buried in mud or sand, where after death only the soft parts perish. The proportion, therefore, of those which are preserved should by far exceed that of any other division of the animal kingdom. Accordingly, as we have before remarked, two-thirds of the known species of fossils are shells, and we are

not surprised that fossil shells should constitute the greater portion of numerous strata of the fossiliferous rocks of all ages. Remains of naked molluscs, the Tunicata and others, however, are rare, and most of these consist of some solid internal part. Extremely rare, nor perhaps free from doubt respecting their nature, are the instances of petrifaction of the soft parts of molluscs.

Of the several classes, the shells of the gasteropods and conchifers are most solid and durable, and the latter most abound in species whose habit is to live buried in sand or mud. Yet in the older formations they are either very rare, or entirely wanting, and the shells of the cephalopods and brachiopods are far more abundant, although at the present time they are extremely rare. Whence it may be safely inferred that the proportions of these great classes have been totally reversed.

On account of the great number of fossil shells, it would be interesting and instructive to pursue these inquiries into the detail of orders, families and genera, but such an amount of detail would not consist with the plan of this introductory sketch.

Of the *nematoneura*, the echinodermata are covered with shells, which are densely crowded with calcareous portions only less solid than the shells of molluscs and cirrhopods, and from their marine habits and great numbers are likely to be preserved. Their remains are by no means rare in many of the formations.

The rotifera and bryozoa are not uncommon in a fossil state, as they have hard parts which are siliceous or calcareous, and are aquatic. Of the parasitic classes of nematoneura, it would perhaps be premature to say much of the probability of their existence in a fossil state; less solid, however, than most of the other classes of this divison, they are less likely to have been preserved, if they existed.

Of the *Acrita*, from the soft bodies of the sterelmintha and their situation, parasitic in parts of animals destined to petrifaction, we should not expect their preservation. The acalephæ, although marine, being mere gelatinous masses, with but a few grains of solid matter, are very unlikely to be preserved. The absence of the remains of these classes from geological formations affords, therefore, little proof that they did not exist. Of the polygastric animalcules the many which had shells of flint leave their shells in extensive deposits, as before remarked.

Of the polypi a few species are naked, and although marine, their soft gelatinous bodies could scarcely be preserved. But the great number of coraliferous species are engaged in the involuntary labors which we have before described, and whose durability is proved by the remains of corals in nearly all the fossiliferous rocks, and beautifully described in the following lines of James Montgomery:

"I saw the living pile ascend,
The mausoleum of its architects,
Still dying upwards as their labors closed;
Slime the materials, but the slime was turned
To adamant by their petrific touch.

"Frail were their frames, ephemeral their lives,
Their masonry imperishable. All
Life's needful functions, food, exertion, rest,
By nice economy of Providence,
Were overruled, to carry on the process
Which out of water brought forth solid rock.
Atom by atom, thus the mountain grew
A coral island, stretching east and west;
Steep were the flanks, with precipices sharp,
Descending to their base in ocean gloom.
* * * * * * *
Compared with this amazing edifice,
Raised by the weakest creatures in existence,
What are the works of intellectual man,
His temples, palaces and sepulchres?
Dust in the balance, atoms in the gale,
Compared with these achievements in the deep,
Were all the monuments of olden time.
Egypt's grey piles of hieroglyphic grandeur,
That have survived the language which they speak,
Preserving its dead emblems to the eye,
Yet hiding from the mind what these reveal;
Her pyramids would be mere pinnacles,
Her giant statues, wrought from rocks of granite,
But puny ornaments for such a pile
At this stupendous mound of catacombs."

The porifera or sponges consist of the fibrous portion known by this name in commerce, and a slimy mass which envelopes the fibres. Dried sponges are frequently found on the sea shore, and some of these with many of the species inhabiting deep water may be buried and fossilised. So fine is the texture and permeable to mineralising agents, that the microscope investigations of late years have shewn that many flint nodules in the chalk consist of siliceous petrifactions of sponges. They are not numerous in the formations and had they existed abundantly in the most ancient periods, it is probable that their remains would have been abundantly preserved.

It remains now to consider some general laws of the organic nature of the present epoch as illustrating a few great principles of very important application in the study of fossils.

The *geographical distribution* of species of animals and plants is a subject of great importance in its application to geology. Although the subject is so copious in its details that it can never

be exhausted, a few outlines may be sketched as sufficient to give some general view. The common observer, who is unaccustomed to careful discrimination between the specific, especially of small animals and plants, which nearly resemble each other, is not aware of the great difference between the Fauna and Flora of different countries. Thus of the species of shells in the West Indies, probably less than one in fifty exists in the New England States. The native quadrupeds of America are specifically distinct from those of Europe. Of the countless hosts of insects, few are common to both sides of the ocean, except those which have been transported by human agency. With a few exceptions, which may perhaps be resolved into the general rule, species are distributed as if they had originated in certain centres, and had subsequently spread until they have met with a hostile climate, or with some obstacle which they cannot pass, or with regions which do not afford them the nourishment they require, or possibly in some cases there may not have been sufficient time since their creation for them to have reached their utmost limits.

Climate has a most marked influence. Let any one travel from home a thousand miles of latitude, and he will find that he has left behind him a great majority of the familiar species. Let him go two thousand miles, and the appearance of a single species which he has been accustomed to see, will be an era in his wanderings. Not only so, but there will be a striking difference in the more comprehensive groups: whole genera, families, or even orders have disappeared and new ones surround him. On the other hand an equal change of longitude will present no such change in the more comprehensive groups, nor in the species except to a limited extent, or as there may be intervening barriers of mountains, water, &c.

In some cases whole tribes of animals and plants, and in others the individuals of particular species only in a genus, are equally affected by climate. Thus the whole tribe of palm trees and many families of shells, either exclusively or with the exception of a few of the smaller and less characteric species, such as the convoluta* with their richly colored and highly polished species, are found in great profusion only in hot climates. The oaks, if found within the tropics, are on elevated regions where they have the climate proper to a higher latitude. Again, there are some genera which exist in all climates, as the Helix (snails,) but are represented in each climate by peculiar species. In most cases there exist peculiarities by which the experienced naturalist can distinguish the species of one climate from those of another. Rarely the same species exists in very different cli-

* A family embracing the cones, olives, and cowries.

mates; as among the molluscs, Lucina divaricata is found throughout the West Indies, in the Mediterranean, and as far north in this country as Long Island; and Pholas costata occurs in Massachusetts and in Florida. A peculiar class of examples of this kind are the migrating animals, which find a greater uniformity of climate by changing their abode as the season changes. From these facts we should expect, if the climate had ever been uniform over the surface of the earth, that species would have had a much wider geographical range than at present, and this appears to have been the fact in the earliest periods.

But not climate only, other circumstances restrain species within certain limits, and even more comprehensive groups have a more or less restricted station.* Bodies of water interpose an obstacle to the distribution of terrestrial species; fresh water to the marine, and salt water to the fresh water species. Deserts and mountains separate zoological as well as political provinces. Islands have their peculiar Fauna and Flora. Some species can exist only on certain geological formations; thus the larger and heavy land shells of some tropical countries exist only in limestone regions, and the land shells of this country are far more abundant in such districts, although not exclusively confined to them. Some require dry and others wet land; some pure and others impure water; some live on sand, others in mud; some on high land, others on low land; some in deep water, others on the shore. A few species again can accommodate themselves to a variety of stations. All these details it is the business of the zoologist to investigate, and on him consequently the geologist is dependent for the means of drawing conclusions.

Sometimes there is a peculiar grouping of species; as when a river flowing into an estuary mixes terrestrial, fresh water, and marine species in the same deposit; or when beasts of prey drag into caves the carcasses of various animals; or when the hermit crabs,† so abundant in hot climates, and with amphibious habits, occasionally mingle terrestrial and marine shells on the open coast without fluviatile agency.

In the application of these general facts to the case of fossils of extinct species in older formations it will follow that no *universal* rule can be given by which to determine whether a given species inhabited a hot climate or otherwise, but that the decision must depend on the zoological affinities of the species. If this belongs to a group which is found exclusively in the tropics, the probability that it was tropical will be very strong, and if a large number of such species are found in the same formation without any other which are proper to colder climates, the conclusion may be considered certain. If, however, the extinct species belong to a group whose species are found in all climates, and it has none of the distinctive marks of climate on it, it will fail of establishing any conclusion respecting the climate.

* The *kind* of place in which a species lives is called its station.

† Crabs,—whose instinct leads them invariably to enter the empty shells of dead molluscs for the protection of their bodies, which are not sufficiently protected by the thin crust with which they are covered,—are called, 'hermit crabs.'

From the peculiarities of station which characterise not only species but more comprehensive groups, the geologist is usually able to make very interesting and important inferences respecting the geography of a region, as it was at the time when the species now extinct was in existence.

Fossil shells shew whether the deposit was made in fresh or salt water; or if species of both the fresh and salt water are mingled, it will be generally inferred that the deposit, especially if the layers form a basin-shaped depression, was made in an estuary into which a river emptied. The depth of the water may often be inferred from the genus to which the fossil belongs. The character of the shells will also shew whether it was a sandy or a muddy shore; in this particular, however, merely confirming the inferences made from the mineral characters of the strata. Fossil plants will shew not only the temperature of the climate, but its humidity, and the general features of the surface. The geological student will find in the copious details of the science, with which we are not here concerned, that the inferences are as full of interest, as are the zoological premises from which they are made.

Extinction of Species.

Since the vast majority of the species and many entire genera and families, whose remains are found in a fossil state, have long since become extinct, any facts of a similar character within the historical period become invested with extraordinary interest. Of so recent a date, however, is zoological science, to which alone we can look for any information respecting the countless host of small species which people the air and the waters, that the facts are few and relate only to the larger species. We shall hereafter see that the extinction of the fossil species was owing chiefly to gradual changes of climate, aided by volcanic convulsions and by mutations in the distribution of land and water. Since the existence of man, his agency has had a marked effect in the more or less complete extermination of some species, and in the increased development of others, to subserve his purposes. Many quadrupeds, as the beaver, wolf, bear, &c. are now extinct in Great

Britain. The perseverence with which the fur trade is carried on is rapidly tending to the extermination of many species.

"Immediately after South Georgia was explored by Capt. Cook, in 1771, the Americans commenced carrying seal-skins to China, where they obtained most exorbitant prices. *One million two hundred thousand skins* have been taken from that island alone, since that period; and nearly an equal number from the island of Desolation! The numbers of the fur-seals killed in the South Shetland Isles in 1821 and 1822, amounted to three hundred and twenty thousand. This valuable animal is now almost extinct in all these islands."

"An extraordinary bird, a native of New Zealand, of which but few living individuals are known to naturalists, appears to be on the point of extinction; it is the *Apteryx australis*." "This bird is of a greyish brown color, and has neither wings nor tail." "The feathers are long and loose, like those of the Emu, but each plume has only a single shaft." "The Dodo was a bird of the gallinaceous tribe, larger than a turkey, which abounded in the Mauritius and adjacent islands, when those countries were first colonized by the Dutch, about two centuries ago. This bird formed the principal food of the inhabitants, but it was found to be incapable of domestication, and its numbers therefore soon become sensibly diminished. Stuffed specimens were preserved in the museums of Europe, and paintings of the living animal are still extant in the Ashmolean Museum at Oxford, and in the British Museum. But the Dodo is now extinct—it is no longer to be found in the isles where it once flourished; and all the stuffed specimens are destroyed. The only relics that remain, are the head and foot of an individval in the Ashmolean, and the leg of another in the British Museum. To render this illustration complete the bones of the Dodo have been found in a tufaceous deposit beneath a bed of lava, in the Isle of France; so that if the remains of the recent bird alluded to, had not been preserved, these fossil relics would have constituted the only proof that such a creature had ever existed on our planet."—*Mantell.*

In Iceland a large species of elk became extinct, probably not long after the island was inhabited by man.

"Its remains commonly occur in the beds of marl beneath the peat-bogs." "In Curragh, immense quantities of the bones of the elk lie within a small space, as if the animals had assembled in a herd; the skeletons appear to be entire, and the nose is elevated, the antlers being thrown back on the shoulders, as if the creatures had sunk in a morass, and been suffocated." "The skeleton is upwards of ten feet high from the ground to the highest point of the antlers, which are palmated, and from ten to fourteen from one extremity to the other." "In the county of Cork, a human body was exhumed from a wet and marshy soil, beneath a bed of peat eleven feet thick; the body was in good preservation, and enveloped in a skin covered with hair, which there is every reason to conclude was that of the elk. A rib of the elk has also been found, in which there is a perforation that evidently had been formed by a pointed instrument while the animal was alive, for there is an effusion of callus or new bony matter, which could not have resulted from something remaining in the wound for a considerable period; such an effect, indeed, as would be produced by the head of an arrow or spear. There is, therefore, presumptive evidence that the race was extirpated by the hunter-tribes who first took possession of the British Islands."—*Mantell.*

But the most remarkable of all the species which have become extinct within the historical period is the *Dinornis*, a genus of birds of enormous size, far exceeding the ostrich. Their bones are found in recent deposits in New Zealand, and the natives have a tradition of the former existence of this bird, which they called Moa. It was allied to the Apteryx in its characters, being without wings. The thigh bone of the larger species was upwards of two feet in length. Being the only land animal in that country of sufficient size to furnish food to the people, it was probably exterminated by the early inhabitants.

These are the only animals which are known to have become extinct since the commencement of man's existence. Many which flourished during the periods immediately preceding have since become extinct, but so slow are the changes in nature and so long is an entire period, the unit in geological computation, that it is not easy to determine whether any such were in existence in the earliest days of our race.

Introduction of Species.

Connected with this question of the existence of *species* is that of their *introduction. How* and *when* does Creative Power introduce the new species? Geology shows us that they have been introduced from time to time during long periods. Have any such instances occurred in modern time? Some suppose that the introduction of species forms a part of the present order of things. If it is difficult to learn the precise time when species die out, much more is it to determine the year or the century of their introduction. If they are now introduced from time to time, it is not probable that such an event is more frequent than the extinction of others, and as it would from the numerical preponderence of the smaller and inferior tribes be more common among them, it might occur frequently, without being demonstrable. When species before unknown are discovered, the inference is, not that they have been created within a few years, but that they have been overlooked. It is only when the view is extended through periods in which centuries dwindle, like terrestrial distances seen from the planetary spaces, into an invisible insignificance, that we may speak with confidence of the gradual introduction and extinction of species.

The question *how species are introduced* has been much discussed, and some of the theories have been supposed to conflict with the great truth of religion, that the species are created by a Being of infinite intelligence and goodness. Some writers, therefore, with a zeal not according to knowledge, have made upon these theories attacks which are too quixotic to engage the attention of sober science. Whether species are introduced by a special act of creation, or whether the actions of the Supreme Being in this as in other events of nature have such a uniformity and such fixed principles, that we may call them laws of nature, is a question which should disturb no man's religious belief. Our limits, however, will not permit us to discuss either the theories or the objections to them, and we can merely give a synopsis of the former without adducing any of the facts with which they are connected.

One theory supposes that species are introduced by a direct *creative* agency, which is of the nature of a miracle, that is, cannot be referred to any uniform course of nature. Such would perhaps seem to be the origin of man as related in the sacred writings, which, however, give us no details of the creation of other species. Nor can any argument from analogy be drawn from his creation to that of other species, since, zoologically considered, man is an anomaly in the animal kingdom, and the case is rather one of contrast than analogy.

Another theory is that of *transmutation*, which supposes that beings of the most simple organization having somehow come into existence, the more complex and the higher orders of animals have originated in them by a gradual increase in the complexity of their structure. Of this theory there have been various modifications. It was supposed by Buffon* originally, that there were elementary particles of living matter, viz. animalcules, whose fortuitous aggregation formed larger animals, which are, therefore, only heaps of animalcules. Lamark supposed that animalcules are elementary particles of living matter, but that the larger animals were formed from them by the process of appetency which we shall presently notice. The basis of this theory, and the basis and superstructure of Buffon's theory, were overthrown by those naturalists who discovered that animalcules have a very complicated organization. The doctrine of appetency supposed that new organs are formed in animals before destitute of them, by the existence of desires in the animal constantly tending in a given direction. Thus the desire of masticating food produced teeth, the desire of handling made hands and fingers grow, &c. This seems sufficiently absurd, and those who have adopted the theory of transmutation have generally detached it from this absurdity, and not attempted to explain *how* the process of transmutation goes on.

It was never supposed that the process of transmutation was so rapid that any perceptible process could be made within the limits of human observation. But the long periods of geology are supposed to afford ample scope, and the idea formerly prevailing, that the species which first existed were of the simplest forms, and that the more complex were gradually introduced, gave it countenance. The geologist, however, finds that some of the higher orders, were among the early inhabitants of the globe, and that

*Buffon, although a voluminous writer on Natural History, was not a practical naturalist, and his writings have had most influence among the unlearned, who are always theorizing without regard to facts.

while in some portions of the animal kingdom there has been a gradual introduction of the more complex forms, in others the process has been retrograde.

Another theory is that of equivocal generation, which is not exclusively applied to the introduction of species, but which supposes that individuals of species, which may or may not have pre-existed, may be generated by circumstances supposed to be favorable to such a process. It once had a wide application, and bees, flies, snakes, weeds, mushrooms, &c. were supposed to be formed in this manner. The substitution of the rigid and exact observation, which characterise modern science, in place of the idle speculation of former days, and especially the aid of the microscope, have shown the relation of parent and offspring to exist in most of these cases, and the unexplored portions of nature to which this theory is applied, are greatly reduced. The inquiries on this subject, without confirming this theory, do, however, extend our views of the vitality of seeds, and of the inferior forms of animal life. Seeds which have been dormant for centuries have been made to grow, and every one knows that the clearing of woodland is often followed by a different growth of timber, whose seeds have been for centuries dormant in the shade of the forest, which doubtless once choked and exterminated the growth from which those seeds were derived. Animalcules are known to exist for years without manifestations of life, in a state of dry powder, the sport of the winds, and on application of moisture have revived.

Duration of Species.

We must notice briefly a question of great interest to the geologist and to any philosophical observer of nature, the *duration of species*. Nature has not left the individuals of species without many safe-guards against the dangers to which they are exposed. Yet multitudes of seeds perish without germination, and the greater portion of the animal kingdom perish by violence, long before reaching the limit of which their life is susceptible, so that a 'natural death' is rather the exception than the rule in nature. But the life of a species, if we may so speak, is far more carefully guarded. To every species is given a degree of fecundity far beyond that which would be required for its perpetuity, if not exposed to occasional accidents and disastrous seasons; while, for the excessive multiplication consequent on a favorable season, checks are provided in the limited supply of nourishment, and in the enemies which increase by this increase of their prey. Thus individuals may perish in countless myriads, but the species endure from age to age, and not a few of the feeblest and most minute species have existed many times longer than man himself.

Without the aid of geology, zoology can give us no information on the duration of species, for in the rare cases where a species has become extinct within the historical period, it teaches nothing respecting the origin of those species. Happily, however, the case of some species now in existence, and whose remains are found in some of the Tertiary strata is full of instruction. Of the twelve hundred and thirty eight species of shells, which existed in the earliest of the Tertiary periods, forty-two are yet living. If now we can satisfactorily account for the longevity of these species or even discover any condition connected with it, we shall obtain a view of principles which are highly instructive on this subject.

Some of the species, which have thus survived the changes on the earth's surface that have proved fatal to most of their former cotemporaries, have a wide geographical distribution, which

"Indicates a capacity of enduring a variety of external circumstances, and which may enable a species to survive considerable changes of climate, and other revolutions of the earth's surface." (Lyell.)

Lucina divaricata is an example before mentioned; Saxicava rugosa, now living on the shores of Europe and America, is found in the Pleistocene deposits of both countries, and as far back as the Eocene in Europe.

If thus a species is capable of enduring extremes of climate in a wide geographical range, the probability that it is a long lived species may be inferred. Among fossil species, therefore, those which occur in several successive formations are the more likely to be found in the strata of distant countries, or conversely, those which are known to have this wide geographical range, are less likely to be restricted to a single formation.

Others which have also survived the three great Tertiary periods, or in the language of Mr. Lyell, 'have like Nestor survived three generations, are species, which, living in deep water, find a uniformity of temperature and of other conditions, which do not exist at the surface. Such frequently have, from this cause rather than any innate capacity of endurance, a wide geographical range.

Others again are species which have gradually migrated into warmer latitudes as the climate has gradually become colder. Several species of shells which are now found only in a fossil state in middle Europe are living within the tropics. Hence we should derive a caution in inferring the cotemporaneousness of distant formations from the identity of a few species, for it is possible that some of these formations may have had the same climate at periods, which, although not far distant on the geological scale, may yet have been by no means contemporaneous.

Of the several divisions of the animal kingdom, the species of

some are much more enduring than of others. Of the mammals no living species can be traced farther back than the most recent of the Tertiary periods. The fossil remains of birds are perhaps too few to warrant any positive generalisations, but those which have been found belonging to former periods are distinct from any now living. Of fishes which have been found in greater or less numbers in nearly all the fossiliferous rocks, it is said that the same species is never found in two successive formations. They are therefore the most serviceable in determining the cotemporaneousness of distant formations.

The duration of genera and of the more comprehensive groups, may be more appropriately considered in another place.

Determination of Organic Remains.

Were we permitted to go into detail, it might easily be shown in what manner important inferences may be drawn from very imperfect remains of animals and plants. Often only a tooth, or a few scattered fragments of bones, or even the tracks may be all the relics which remain to testify to the character of the extinct species. The determination of the character of organic remains, therefore becomes a problem of the highest importance, and often taxes to the utmost the resources of science. Nor is it a question of scientific interest only, for since the real character and the age of the rock is to be determined usually by the nature of the organic remains, it becomes a question of great practical interest.

We have before shewn the nature of the aid which is derived from a minute acquaintance with the species which are now living. But not only zoology and botany contribute from their boundless resources to the aid of the geologist, comparative and vegetable anatomy render no less efficient aid. These sciences examine the parts of animals and plants and

"Reveal to us the astonishing fact, that so mathematically exact is the proportion between the parts of an animal, that from the character of a single limb, or even from a single tooth, or bone, the form and proportion of the other bones, and the entire animal may be inferred! Hence not only the frame work of the fossil skeleton of an extinct animal, but also the character of the muscles, by which each bone was moved, the external form and figure of the body, the food, and habits, and haunts, and mode of life of creatures that ceased to exist before the creation of the human race, can with a high degree of probability be ascertained." (Hk.)

This, although extraordinary, is not so mysterious as might at first appear. Every tribe of animals has some peculiarities, of which some are necessarily connected, and others are invariably associated without any obvious connection. An example of the necessary relation between parts may be seen in the relation of the claws of the tiger, or of any kindred species, to the other parts of the animal. The sharp curved retractile claws are fitted for seizing and tearing its prey, and all the other parts appear to be necessarily associated with them. The teeth must be sharp, and adapted for cutting flesh rather than for bruising grain: the food being flesh, the digestive apparatus must be less complicated, and the intestines not a quarter as long as in herbivorous animals; and the general form and structure must be consistent with agility in order to seize the prey. All these and many more details would be inferred from finding a single retractile claw, whether it should belong to any known or unknown species, and with the aid of zoology, all the general characters of the tribe of carnivorous mammals with their anatomy and physiology in their numerous details would also be inferred. Of the characters which are associated without apparent reason, we have a striking example in the ruminants, for every cloven-footed quadruped chews the cud, and thus the number of stomachs is infallibly inferred from the characters of the foot. The naturalist is familiar with numberless examples of this curious principle in zoology. It extends even to color and clothing as well as to form and structure, so that certain colors only will be found in certain species or groups of species.

Both of these principles are familiar facts in reference to well known animals. A single tooth of a horse will shew not only to what kind of animal the tooth belonged, but even his age; and every one knows that a green horse, a blue dog, or a red elephant are as unlikely to exist, as a ruminating quadruped with four toes or with a solid hoof. Now those who are as familiar with the various tribes of organic nature, as the husbandman is with his cattle, are able to make similar inferences respecting the multitude of species with which the mass of mankind are unacquainted. Thus when a single tooth of the iguanodon was shewn to Cuvier before the discovery of the skeleton, he laid down the characters and habits of that herbivorous reptile with an accuracy, which the subsequent discoveries have only confirmed. A single fish scale was found in the intestines of an ichthyosaurus, and shewn to Agassiz, who recognized it as belonging to an extinct species known to him, and he was able to point out the part of the fish to which it was originally attached.

In the vegetable kingdom, although many general inferences may be made from parts, yet details cannot often be deduced in this way, and the geologist finds fragments of plants without being able to decide whether they belonged to the same or to different species.

Comparative number of living and fossil species.

It may be interesting to shew in a tabular form the comparative number of species known to be living and of those which

have been found in a fossil state, which we shall do of course only in round numbers.

Classes or divisions.	Living species.	Extinct species.
Mammalia.	1300.	275.
Birds.	8000.	20.
Reptiles.	?	120.
Fishes.	8000.	900.
Insects.	100,000.	250.
Articulata, (other than insects).	?	500.
Molluscs.	12,000.	6000.
Polypi.	?	900.
Echinodermata.	?	200?
Animalcules.	800.	100.
Plants.	100,000.	800.

In this comparison, the first column comprises the species of one period, and the second, those of hundreds of periods. This discrepancy is owing mainly to three causes: the liability of many tribes to perish without being fossilized; second, the small portion of the fossil remains which appear on the surface, the great majority being concealed within the strata, while the living species are on the surface, and exposed to notice also, in the case of many animals, by their habits of activity; and third, the greater number of observers and collectors of the existing species of animals and plants. Of so much much consequence are these three principal circumstances, that with some exceptions it would be mere speculation to make a definite comparison in the actual number of the living and of the extinct species.

A very obvious inference from the history of organic remains is, that the greater part of existing continents have been under the ocean since the commencement of the palaeozoic period; for they are, with the exception of some primary mountainous districts, and some very limited fresh water formations, covered with strata which abound with marine fossils. These fossils with scarcely any exceptions are the remains of animals and plants, which lived and died in the places where they are now found, as is attested by the preservation, in numerous instances, of parts so delicate, that they would have been destroyed by transport, and also by the nature of the stratum in which they are found corresponding to the known station of kindred species now living. Since also some thick deposits thin out in certain directions, it may be inferred that the materials of which they are composed were derived from the opposite direction; in other words that there was an island or continent in that direction, the size of which and of its rivers must have been in some measure proportionate to that of the formation derived from it.

From the alternation, in some cases, of fresh water with marine formations, it is also obvious that some portions of the earth have been subject to both elevation and subsidence repeatedly.

It appears to have been the general fact, that the palaeozoic formations with their fossils were uniformly spread over much more extensive areas, than are the secondary and tertiary formations,—not that there is an abrupt change from the former to the latter, but that in general and gradually the deposits are more limited as they are more recent. This would seem to prove that the ocean was shallow over very extensive areas, which would be the consequence of the limited extent of dry land, and is inferred from the general character of the organic remains.

It is also a very interesting fact, that in the secondary and palaeozoic formations the proofs of a warm and even a torrid climate abound. It would seem that there has been a gradual diminution in the heat of the surface from the earliest periods. The organic remains, in countries which are now subject to the rigors of a cold climate, are of a highly tropical character. It would appear also that the climate was more nearly uniform through the different zones, and accordingly species were more widely distributed. The uniformity in the species of widely distant regions is most remarkable in the vegetation of the coal period, even more so than in the animals of more ancient periods.

"It appears that, out of 48 species from Nova Scotia, without enumerating the different species of *Stigmariae*, which agree perfectly with the varieties found in England, there are no less than 37 which have been identified. The part of the remaining eleven might perhaps have been found to agree with known European fossils, had not most of the specimens been in too imperfect a state to admit of close comparison.

"Out of 53 species obtained by me from the coal-fields of the United States, almost all of them from Pennsylvania, Maryland and Ohio, I have been able to identify 35 with European fossils, chiefly species found in Great Britain. Of the remaining 18, only four can be said to be peculiar forms, the other 14 being all closely allied species, or geographical representations of European plants. When it is considered that *all* the *genera* of these fossils are likewise common to North America and Europe, we seem entitled to declare that so great a degree of uniformity in regions equally remote is without parallel."—*Lyell.*

CHAPTER II.

HISTORY OF THE EARTH.

We proceed now with a hasty sketch of the geological history of the earth. It would seem more natural in a historical science, to commence with the most remote period of antiquity and to follow down the course of time. On the other hand the condition of the earth in its earliest ages was so unlike the present, in its geography, its climate, and all its features, that there is little in common between the most ancient and the present period, except that the same material atoms and the same laws of nature remain. He who for the first time becomes acquainted with this extraordinary history, is lost in the strange scenes of those earliest days, unless proceeding step by step from the present to the past, he shall have become gradually accustomed to the change. Without deeming myself pledged to the same course on any future occasion, I shall, therefore, offer myself as a guide in hastily tracing up the stream of time into the remote regions of the past.

Tabular view of the geological formations.

It will be recollected that on a previous occasion we enumerated six classes of stratified rocks. Of these the oldest are called primary strata, and are characterized by their position, beneath the palaeozoic rocks. They are crystalline in their structure, and contain no fossils; but this is also true of some rocks, which are less ancient but have been altered by heat. The second class includes those strata which contain the remains of the earliest organic beings, and a long series of subsequent formations. These were followed by the secondary and these by the tertiary strata. The fifth and sixth classes, drift and alluvium, are by some comprised in one with the name of quaternary. The accompanying table is intended to exhibit most of the formations in these classes, in the order of their superposition. The first column gives the names of the classes; the second, of the orders into which the classes are divided; the third, of the systems, or groups; the fourth, of the divisions, and the fifth, of the formations; in the sixth column we have the thickness in feet, and in the last, the names of some countries where the formations are well developed. The table is of course incomplete, not only because the haste with which it has been prepared does not permit research, but because the progress of geology is continually intercalating formations newly discovered, among those which are well known.

TABULAR VIEW OF THE FORMATIONS.

Classes.	Orders.	Systems or Groups.	Divisions.	Formations.	Thickness.	Countries.
Alluvium.					Variable.	
Quaternary		Quaternary System.		Newer Pleistocene.	200	Southern States Vt. Canada.
				Older Pleistocene.		
				Drift.	Variable.	Northern States Brit. Am. and North'n Europe
Tertiary. Cainozoic.				Pleistocene.	2000	England, Italy, France, Southern States.
				Meiocene.	500	
				Eocene.	1000	
Secondary. Mesozoic.	Newer Sec'dy. " Mesozoic.	Cretaceous System.	Chalk.	Maestricht beds.	1000	Southwestern States, New Jersey, England, West'n Europe.
				Chalk with flints.		
				Chalk without flints.		
			Green sand.	Upper Green Sand.	480	
				Gault.		
				Lower Green Sand.		
	Middle Secondary. Middle Mesozoic.	Wealden.		Weald Clay.	900	England.
				Hasting's Sand.		
				Purbeck Strata.		
		Oolitic System.	Upper Oolite.	Portland Stone.	500	
				Portland Sand.		
				Kimmeridge Clay.		
			Middle Oolite.	Upper Calcareous Grit	450	
				Coral Rag.		
				Lower Calcareous Grit		
				Oxford Clay.		
				Kelloway's Rock.		
			Lower Oolite.	Cornbrash.	450	
				Forest Marble.		
				Great Oolite.		
				Carbonaceous and Stonesfield Slate.		
				Inferior Oolite.		
				Calcareo-siliceous sand		
	Older Secondary. Older Mesozoic.	Liassic System.		Upper Lias.	700	
				Marlstone.		
				Lower Lias Shale.		
				Lower Lias Limestone.		
		Triassic System.		Variegated Marls or Keuper.	900	Germany, Massachusetts, & Connecticut.
				Muschelkalk.		
				Bunter Sandstone.		

Classes.	Orders.	Systems or Groups.	Divisions.	Formations.	Thickness.	Countries.
Palaeozoic.	Newer Palaeozoic.	Permian System.	Magnesian Limestone.	Zechstein.	500	England. Germany.
				Bituminous and Argillaceous Schist.	300	
				Lower New Red.		
		Carboniferous System.	Seral Series.	New Shales.	5700	New Brunswick, Virginia, Ohio, Michigan Pennsylvania, England, Illinois, Kentucky.
				New Coal Measures.		
				Older Shales.		
				Older Coal Measures.		
				Siliceous Conglomerate.	1400	
			Vespertine Series.	Shales and Sandstone.	3000	Western States, Virginia, Pennsylvania.
				Carboniferous Limestone.		
				Lower Red Shale.		
	Middle Palaeozoic.	Old Red System. Devonian System.	Upper Division.	Yellow Quartzose Sandstone.	10000	Russia, Scotland, Pennsylvania, Ohio, Michigan.
				Impure Limestone.		
				Gritty Red Sandstone.		
			Middle Division.	Grey Fossil Sandstone.		
			Lower Division.	Red and Variegated Sandstone.		
				Bituminous Schists.		
				Coarse Gritty Sandstones.		
				Great Conglomerate.		
	Older Palaeozoic.	Upper Silurian. New York System.	Erie Division.	Chemung Group.	1500	Western States, New York, Great Britain.
				Portage Group.	1000	
				Genesee Slate.	150	
				Tully Limestone.	16	
				Hamilton Group.	1000	
				Marcellus Slate.	50	
			Helderberg Series.	Corniferous Limestone.	70	
				Onondaga Limestone.	14	
				Scoharie Grit.		
				Cauda Galli Grit.	70	
				Oriskany Sandstone.	700	
				Upper Pentamerus Limestone.		
				Encrinal Limestone.		
				Delthyris Shaly Limestone.	100	
				Pentamerus Limestone.	80	
				Water Lime Group.	100	
				Onondaga Salt Group.	700	
			Ontario Division.	Niagara Group.	164	
				Clinton Group.	80	
				Medina Sandstone.	350	
				Oneida Conglomerate.	500	
		Lower Silurian.	Champlain Division.	Red Sandrock.	400	Vermont, New York.
				Hudson River Group.	600	
				Utica Slate.	100	
				Trenton Limestone.	400	
				Isle La Motte Marble.	25	
				Birdseye Limestone.	30	
				Calciferous Sandrock.	300	
				Potsdam Sandstone.	300	New York.

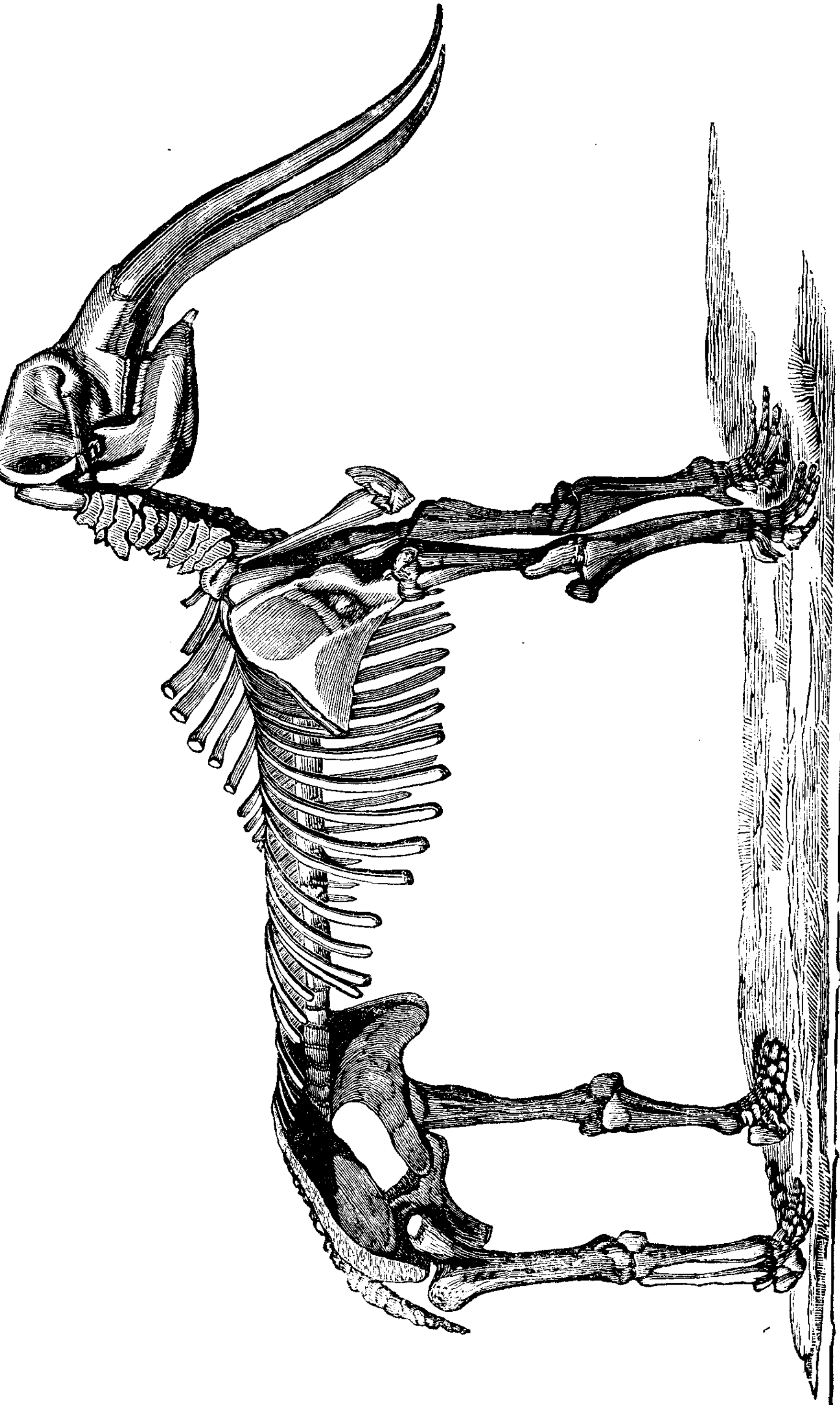


Fig. 5.

With a view of preparing the way for the study of the geology of Vermont, we shall dwell a little on those formations which come within the periods in which the more recent strata of Vermont were deposited, but must lightly sketch the vast series from the Drift to the Champlain division of the New York system, although this series comprises the most extraordinary and interesting chapters of the Earth's history.

QUATERNARY PERIOD.

Newer Pleistocene.

Commencing with the southern or newer pleistocene period, we find at once unaccustomed features of the country and strange and gigantic races of animals. The more depressed portions of the southern states were covered with the waters of the ocean, and as the shells now inhabiting Massachusetts Bay and the Gulf of Mexico were mingled in the basin of the Potomac, it would appear that the climate was uniformly warm, such as would result from the extensive distribution of water, perhaps of the Gulf stream, over considerable portions of the country. The portions not submerged were inhabited by an extinct species of horse, of bison, hippopotamus, elephant, and the great mastodon, and another curious animal like the elephant in size, the mylodon, with those huge quadrupeds, megatherium and megalonyx. Then the mastodon flourished in great numbers in the western states, and wandered as far to the north-east as the Hudson river, for their skeletons are found in bogs of shell marl and in the salt licks of the west. From the great salt lick of Kentucky the bones of 100 mastodons have been removed, with those of the extinct elephant and other animals. Quite recently (August, 1845,) was found in Newburgh, New York, an entire* skeleton of the great American Mastodon, with the head raised and turned to one side, and the tusks thrown upward, the posture natural to a quadruped when sinking in the mire. This being one of the most perfect skeletons, we annex a figure, (Fig. 5.) The stomach was also found, containing leaves and bruised twigs, as had been seen less distinctly in some previous discoveries. The structure of the teeth would have led us to suppose that it fed on the boughs of trees and young saplings, since, differing remarkably from those of the elephant, the grinders are covered with large conical elevations, which must have enabled them to grind such food with great facility, and which once led to the erroneous idea that it was a carnivorous animal. As this was the last

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* The bones of one foot are wanting, and are supposed to have been carried away in the marl, which was removed for agricultural purposes.

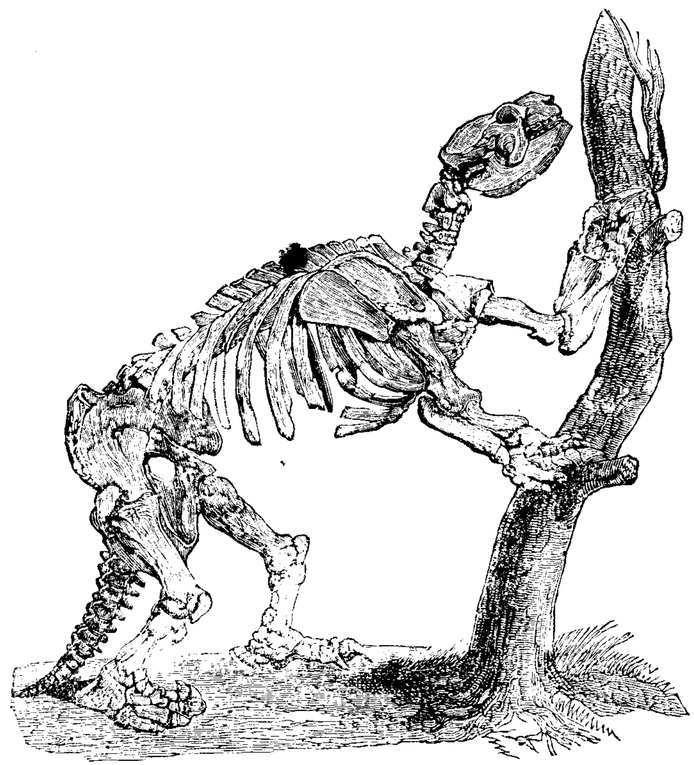
of the geological periods anterior to our own, it becomes an object of great interest to form some conclusion respecting the *time* when these gigantic mammalia flourished. In the more northern portion of their range they are found to have been mired in *shell marl*, which consists of the same species of fresh water shells which now inhabit our waters. That these quadrupeds did not, however, belong to the present period, is obvious from the warmer climate, inferred as above, and also from the beds of muck over the marl beds, which (the muck) could not accumulate during the warm period, when both the warmth and humidity of the climate permitted these small univalve shells to accumulate in thick deposits. But after the change of the climate, the muck has been gradually accumulating to the present time. There is no reason to suppose that any of the mastodons have existed since this continent was inhabited by man, notwithstanding the Indian traditions, which are doubtless crude geological speculations founded on the occurrence of the bones. How long this period continued is not easily estimated. The origin, duration, and extinction of species constitute a longer series of events than has been known to have passed by since the creation of man. Fortunately we have a rude, but grand natural chronometer in the falls of Niagara. There is good reason to believe that before the Drift period, the Niagara river furnished a direct course to St. David's, and that its channel was filled during the period of boulders, clay, &c. Subsequently to the close of that period and the commencement of the one now under consideration, it has excavated the channel from Queenstown to the present falls. The rate of retrocession at the present time is pretty well known; and, although it must have varied, some portions being more and others less easily cut through, the time since the commencement of the pleistocene period is inferred to be not less than 30,000 to 40,000 years.

It is a fact worthy of notice, that, in accordance with the remarks before made on the duration of species, the fresh water mollusca, being less sensitive to a change of climate, which has been fatal to the higher orders of animals, have survived the whole of this long period, and constitute the unchanged Fauna Molluscorum of the present time. This fact is particularly interesting, when we consider that the numerous formations which geologists have established, and a part only of which appear in the foregoing table, are distinguished, for the most part, each by peculiar species of shells. If 30,000 or 40,000 years make no perceptible change in the extinction of former species, and if there are some hundreds of formations distinguished from each other by such extinction, often carried to an entire remodeling of the Fauna, the geologist may well be lost in the immensity of time, as is the

astronomer in the immensity of space. Not without cause have the sacred Scriptures declared, that with Him who directs all these events a thousand years are as one day, and, adding that one day is as a thousand years, they teach us that time is of no account in the plans of Infinite Wisdom.

During the same period several colossal species of quadrupeds now extinct flourished on the vast plains of South America. Some of the most remarkable were the Megatherium, Mylodon, Megalonyx, Scelidotherium, some of which had bones much larger than the elephant, although the entire bulk of the animals was not greater. The feet, legs, pelvis, and tail of the Mylodon were of enormous dimensions, enabling them, as they rested on the firm basis of their massive hind legs and short thick tail, to tear down large trees, whose roots they may have loosened by their enormous claws and fore feet; which last (in the kindred Megatherium) were one yard long.

Fig. 6.



[Mylodon robustus.]

During the same period, also, there lived in Great Britain many quadrupeds, most of which, including all the larger species, are extinct, as an extinct species of elephant, of bear and of hyena larger than any now living, of horse, lion, tiger, &c. These occur with some, as the great Irish elk, before mentioned, which became extinct since the existence of man, and others, which are yet in existence, as the fox and wolf, thus showing that the extinction of species of that epoch was a gradual, and not a sudden and violent process.

Probably, also, the gigantic birds of New Zealand existed during the same period, although continued into the historical epoch.

DRIFT PERIOD.

As the members of the drift division have a full development in Vermont, the general geology of this period claims some consideration. The features of the surface and the physical changes of that period will be found still more unlike the present order of things. We must, therefore, before coming to the conclusions which constitute its history, carefully examine those mementos of it, which we find abundantly scattered over a large portion of the country.

The deposits of this period cover this continent north of 40° north latitude, and in the valleys of the Delaware, Susquehannah, and Mississippi, they extend a few degrees farther to the south. A large part of Europe, Great Britain, Norway, Sweden, Russia, and the countries south of the Baltic, are covered with similar deposits. Drift also occurs in similar latitudes in the southern hemisphere, as in Patagonia, and the Falkland Islands. It appears to be wanting within the tropics, for the few accounts, which have been given of its existence in the West Indies, are based no doubt on the deposits of rivers flowing at higher levels and subject to violent freshets.

The deposits of this period are the older pleistocene and the drift. The latter comprises by far the greater part of these deposits, and consists of sand, gravel, hard-pan, pebbles and boulders variously mingled, and frequently shewing a very irregular and confused stratification, as if the result of very turbulent currents.

The deposits of the older pleistocene were formed in the irregular basins of drift, and consist of clays more or less finely laminated and of fine sand. They contain fossils, (some of which are delicate shells evidently entombed in the place where they lived,) and indicate a period of quiet. The subdivisions of this period, as they appear in Vermont, will be considered in another place.

The most important facts relating to this period may be referred to the following heads:

1. The fossiliferous horizontal and regular deposits of the older pleistocene, which are for the most part extremely limited in extent.
2. The absence of fossils from the drift.*
3. Its confused stratification.
4. The transport of drift abundantly over the highest part of the country, not only pebbles but enormous boulders weighing many tons having been carried up steep acclivities.
6. The direction of the transport being towards the south, to south east, rarely a little to the west of south, and never in a contrary direction. To the practical geologist, this fact is as familiar as the alphabet, and the direction of the source to which fragments may be traced was noticed in the first report. This fact is strikingly obvious in the larger boulders. In some cases the materials were transported for hundreds of miles, and frequently for ten or twenty miles. It is truly remarkable how little influence ranges of mountains, oblique to the current of drift, had upon its course.
6. The diminution in the size of the boulders as they are more distant from the parent ledge.
7. The existence of furrows and scratches on the surface of the solid rocks, whose direction corresponds so universally and exactly with the course of the transported materials, that the one may always be taken as the index of the other. Here also the influence of oblique ranges of mountains is usually slight and very local. But some mountain valleys have had an influence more or less marked, two striking examples of which we shall find in the geology of this state.

In some cases on the tops of mountains of the tougher rocks, as on Mt. Holyoke in Massachusetts, furrows are found which are a foot wide and two inches deep. We have seen also, in Dorchester, Massachusetts, the sides of an angle between two portions of a ledge of hard quartzose conglomerate, which was nearly in the direction of the drift, rendered concave and smooth, as if the moving bodies were forced through with great friction.

More frequently the furrows are but an inch to three inches in width and about a third as deep. Still more frequently scratches occur which do not exceed one eighth or one fourth of an inch in width, and others are as fine as the stroke of a pen.

Sometimes the entire surface of the rock is smoothed down, rounded and polished, as in the case of the Dorchester rocks above

*Although the whole period is termed the drift period from its most characteristic deposits, yet to avoid confusion, we shall term the regular deposits pleistocene, and restrict the word drift to the coarser or more confused deposits.

mentioned where the surface of the hard quartz pebbles is in relief, like the siliceous specks in a piece of marble artificially polished.

8. That the scoring is referable to the agency which transported the drift is proved by the coincidence of direction in cases without number: it is also inferred from the following considerations; the superposition of the drift over the furrowed rocks proves that the furrows are at least as ancient as the drift, and there is no reason for supposing that they are more ancient; indeed in the geology of this State, we shall find very satisfactory proof that they could not have been made at any preceding period.

9. In many narrow valleys, or elsewhere, at the foot of mountains, especially on the north side, there are collections of small steep well rounded hills, separated in some cases by equally well rounded concavities, and composed of very loose gravel and pebbles; and the same kind of materials is occasionally found in very long narrow steep ridges, some curved and some more or less straight. These accumulations have been called moraines, and iceberg moraines, from their close resemblance to the masses of earth and stones so called, which result from glacial action.

10. The tops of some slate hills have been crushed over by enormous masses from above striking them with a prodigious force. As most of the known examples have been discovered in this State, we reserve for another place the description of these facts.

11. The southern limit of the drift before mentioned is a fact of great importance.

Such is a general description of the drift of North America. With slight modification it is equally true of the drift of western and central Europe. But in the recent and magnificent work of Sir R. I. Murchison on the geology of Russia, we have a very material addition to the history of the drift of northern Europe. Commencing at the western boundaries of Russia, and proceeding to the north east part of European Russia, the transport of drift is found to be more and more to the east, until at length in approaching the Arctic Ocean, the course is from west to east. In other words, the lines of direction, traced backward, converge towards the crystalline and metamorphic rocks of Scandinavia; and since M. Boghtlink had previously shown that the transport in the extreme north of Lapland was from the south to the north, it follows that the depression of the drift of northern Europe consisted in a series of excentric movements from the Scandinavian centre. We may add that the completion of most of the periphery of the scene of this great drift movement, within the limits of Europe, disconnects it in space from the similar movements in North America, with which it had been commonly associated; while the superposition of the European drift in the vicinity of the Baltic, *over* strata which contain the recent species of shells, and the position of the North American drift, *beneath* strata which contain several extinct with many existing species of shells, demonstrate that our drift is much older than that of northern and central Europe. Nevertheless the remarkable correspondence in general features points to a similar, though *not identical* origin, and leads us to look for similar results, in the future possible discovery of excentric lines of transport over the immense area of this continent lying north of 40° north latitude.

Another example of the excentric dispersion of drift also occurs in Europe in the Alps, whence masses of drift have followed the course of the valleys outwards.

Theories of drift.

The great problem—what was the agency which dispersed the drift, and wore down, smoothed and furrowed the rocky floor over which the materials moved—has elicited many theories. We shall here notice the outlines of these theories, without attempting to describe all their modifications, which have been almost as numerous as the individual writers.

The *iceberg theory* supposes that the drift country was submerged below the tops of the mountains not long before the drift agency, and that a polar current floated down icebergs which were loaded with the materials of the drift, and which, melting in their progress into a warmer latitude, strewed the drift along the bottom of the sea, and scored the surfaces of the rocks beneath, with the fragments of rock which were frozen into the bottom of the icebergs.

This theory has the great advantage of introducing no more violent agencies than are now in operation; such a polar current now exists, as we have seen, bearing icebergs, which are occasionally loaded with gravel, into warmer regions; and probably it would not be denied that if this country were submerged, this current, which now has a strong westerly tendency, would flow over an extensive region; the iceberg moraines are such as would be produced by the stranding of icebergs, either dropping their freight of earth and stones, or crowding up the materials on the bed of the sea by their weight and as they were rocked and urged on by the waves; this agency, it is said, must have acted with greater intensity than at present, because the climate was colder, and the glaciers must have descended from the mountains of New England: instances are now occurring in which masses of ice, having thus frozen stones into the bottom, scratch the rocks over which they are driven. It will be seen that this is a double theory, and although submergence is necessary to the action of icebergs, the theory of submergence may be retained consistently with the rejection of the iceberg theory.

It is, however, objected to the theory of submergence, that the drift appears to be entirely destitute of fossils, although submergence between the older and later drift to the extent of 300 to 500 feet below the present level is admitted, being attested by marine shells as before mentioned. It may also be objected that whether or not icebergs were drifted along, they could not have picked up masses of rock from the valleys and then carried them over the mountains; that on the tops of the mountains rather than in the valleys the scratches should more frequently occur, whereas they are at least as common in the latter situation; that the source of the materials should be found only in higher northern latitudes, rather than within a few miles of the present situation of the fragments; that icebergs would not drop the heaviest stones first; and that the rocky bed of the ocean especially in its valleys, would have been more or less protected by a covering of mud from the furrowing agency of stones frozen into the icebergs. It is also denied, as we shall see in the geology of Vermont, that there is any evidence of a colder climate, at least in the middle period, and it will be shown that the tops of the mountains were not the centres of dispersion but were overflowed in the same manner as the low lands.

The second theory is that of the *glacio-aqueous* agency, which supposes the climate to have become cold at the commencement of this period,

"Whereby all organic life was destroyed; and in high latitudes at least, glaciers were formed on mountains of moderate altitude; indeed, that vast sheets of ice were spread over almost the entire surface extending south as far as the phenomena of drift have been observed. The northern regions, especially around the poles, are supposed to have formed one vast mer de glace, which sent out its enormous glaciers, in a southerly direction, by the force of expansion, and the advance and retreat of these glaciers, accumulated the moraines and produced the striae and embossed appearance (*roches moutonnees*) upon the rocks. When the temperature was raised, the melting of the immense sheets of ice produced vast currents of water, which would lift up and bear along huge icebergs loaded with detritus, and thus scatter boulders over wide surfaces."—(*Hk.*)

In support of this theory, it is urged that a few years since an elephant and rhinoceros, of the species which inhabited Siberia immediately before the drift period, were found with the flesh and skin entire, frozen in ice on the northern shores of Siberia, and that, therefore, there must have been a change from a climate warm enough to produce the food of the elephant whose remains are so abundant in that country, and so sudden that putrefaction would not take place. It is also argued that this refrigeration of

the climate accounts for the absence of fossils from the drift; that the iceberg moraines, the striae, and furrows and smoothing down of the surface of the rocks, and the transport of the detritus, are effects precisely similar to what we see on a smaller scale in the glaciers of the Alps.

To this theory it is objected that such a refrigeration of climate is without any known parallel in the history of the earth, and that it cannot be accounted for without supposing a great derangement, for the time, of the solar system, and that the accumulation of a glacier large enough to cover the northern regions of Europe, Asia and America, is not possible without a chaotic derangement of the whole planetary system; that glacial action is peculiar to the highly inclined valleys of very lofty mountains; that the southerly transport of the drift through a long period is not sufficiently accounted for, even by the sudden melting of the ice, and that the mere expansion of the great glacial sheet could not transport the drift for several hundreds of miles; that the northern part of Siberia is not a proper drift region, and consequently the case of the frozen animals has no connection with the subject; and that the wearing down and striation of the rocks may be otherwise accounted for.

The *theory of elevations* supposes that in the great centres from which the drift emanated, there were violent earthquakes and elevations, oft repeated through a succession of ages, whose shocks threw down over the northern portions of the globe enormous earthquake waves, bearing along the immense icebergs of the polar regions with great violence, and strewing the preëxisting loose materials of the surface far to the south of their former position, and that immense masses of such materials were moved along by receiving a portion of the impulse, which acted on the rocks beneath in the same manner as glaciers, producing similar results. Some of the advocates of this theory suppose that this took place without any actual depression of the continents, although this is not essential to the theory. Some also suppose that instead of simple elevations, there were undulations of the crust of the earth, as in some modern earthquakes, without admitting ice to have had much influence.*

In support of this theory, it is argued that earthquake waves are known, by many modern examples, to consist in the actual locomotion, (if I may use a word characteristic of these times also,) of the water, and consequently to have a momentum inconceivably greater than ordinary waves, and that such waves of transla-

*If however such a region as the eastern part of Iceland, with 3000 square miles of ice mountains, were exposed to such earthquake action, immense numbers of icebergs would be borne along by the waves.

tion might therefore have swept over many degrees of latitude; and it has been proved that a current of twenty miles per hour would transport stones weighing 300 tons.

To this theory it is objected, that repeated elevations could not go on long enough to produce the drift phenomena, before the great central earthquake region would have been elevated above the water. But it is not necessary to suppose that all the earthquake action was elevatory, and it may have comprised, as in modern earthquake regions, a series of both elevations and subsidences: it is obvious that the commotions in the water in the latter case would be far more limited than in the former.

We shall now, as we proposed, offer merely a synopsis of the many and long periods, which intervened between the drift and the Champlain division of the New York system.

TERTIARY SYSTEM.

The formations of this period are

" Composed of layers of clay, sand, gravel, and mud, with occasional quartzose and calcareous beds more or less consolidated; all of which were deposited in waters comparatively quiet and in separate basins"(—*Hk.*) or in more extended areas.

They consist of three or four groups of marine strata, which are separated by other strata that contain freshwater and terrestrial remains.

The *Pleiocene* strata are found in many parts of southern Europe to attain to great thickness; in some places to two thousand feet. They contain abundantly shells of marine species, of which a large portion still exist on the Mediterranean. A deposit on the Rhine contains brown coal in greater quantity than any other above the carboniferous system; but it is of little economical value. A majority of the species of fossile insects are found in the pleiocene of Germany.

The *Meiocene* strata occupy a considerable portion of France, Austria, Poland, and Russia, and, in this country, of Delaware, Maryland, Virginia, and North Carolina. Marine shells are abundant. About seventeen per cent. of the species are yet in existence. Mammals also were very abundant during this and the pleiocene epochs.

The *Eocene* also contains numerous species of shells, of which about three per cent. are yet living. This formation occurs in the south east of England, in the vicinity of Paris, and also in Alabama and South Carolina. The remains of some birds, and of many mammals are found, of which the species, and many of the genera are extinct. The eocene of Germany contains beds of polishing slate, fourteen and twenty eight feet thick, which

consist of the shells of animalcules, at the rate of 41,000 millions to a cubic inch.

CRETACEOUS SYSTEM.

This formation consists chiefly of chalk in the upper parts, and of sands in the lower; the chalk being replaced in this country by the Ferruginous Sand. It is well developed in the south east portion of England, in New Jersey, Alabama, Mississippi, and Arkansas. The fossils are numerous, and are mostly the remains of animals, the plants of this period having been rarely preserved. The flints which are so abundant, are delicate sponges, in which are microscopic shells, petrified and filled with siliceous matter, and which exhibit the spongy structure and the shells under a powerful magnifier. Echinodermata, shells, and crabs are abundant. The hermit crabs make their appearance for the first time in this period. Fishes are common, and several extinct genera of saurian reptiles, one of which, the mososaurus, a kind of lizard, had a head four feet long, and was probably twenty four feet in its entire length.

WEALDEN GROUP.

This group consists of clay, sand, and limestone strata, which contain the remains of terrestrial and fresh water animals and plants. The remains of coniferous trees, and large but undetermined endogenous plants are found. Minute fresh-water crustaceans, and some insects, a few wading birds, and some tortoises, fresh water mollusca, and enormous saurians in great numbers, were the animal kingdom of that period. The fresh water shells were very numerous, and constitute the greater part of some strata of beautiful marble. They belonged to extinct species of the existing genera of paludina, melania, and cyclas. But the reptiles were the most remarkable of the animal kingdom for size, number, and variety. Some resemble the long-snouted gavial of the Ganges, and others were furnished with shorter and more powerful jaws. One of the most extraordinary was the iguanodon, a herbivorous saurian, with some resemblance, especially in the form of its teeth, to the iguana or tree lizard, but of massive proportions. In one respect, it was more like the pachydermata, (thick skinned mammals), than reptiles, for its body was elevated to a considerable height above the ground, the thigh bone being three feet eight inches in length, and thirty-five inches in circumference at the condyles. It is estimated to have been not far from thirty feet in length, although when first discovered, it was supposed, on account of the great size of some of the bones, to have been much larger. That they were very numerous is evident from the discovery of more than seventy in the quarries of one locality in the south of England.

OÖLITIC SYSTEM.

The name oölitic, signifying egg-stones, is derived from the appearance of many of the limestones of this system, which are composed of a multitude of little spheroidal concretions. The strata comprise an extensive group of limestones and clays, and are more remarkable for their economical and scientific importance, than for their thickness and extent. For the subdivisions, the table may be consulted. In England, they are very fully developed.

The system is remarkable for the number and variety of its fossils. Of the plants, extinct species of fossil Cycadeae chiefly abound. This is an order of tropical plants which, although exogenous, resemble short palms, with a magnificient crown of graceful foliage, and a large terminal bud. In the animal kingdom, polypi were abundant, of the tribes which construct extensive coral reefs. The echinodermata were represented by many very singular animals, some of which grew firmly to the rocks by a long stem, (the crinoideans). Crabs and insects have been well preserved, and all the classes of shells are common, but the higher orders are more abundant. Of the cephalopods, one species is found with its ink bag, which it probably used as the cuttle-fish uses its bag, to discolor the waters by a discharge of the inky fluid when pursued by enemies. The well known India ink is obtained from the cuttle-fish, and the ink of a fossil specimen, preserved through the long intervening periods, was therefore tried by an artist and found to be of the best quality.

The fishes and reptiles, however, of this period are objects of more than fifty species of fishes have been found, most of which the greatest interest. In the oölite of England the remains of were of the sauroid family, a family comprising those genera which approach most nearly in their structure, especially in their mouth, to the saurian reptiles, which they also resemble in their ferocious habits. The bill-fish of Lake Champlain, Lepisosteus oxyurus, is one of the few living species of this family. During this period huge marine reptiles appear to have been the lords of creation. One of them, the pleiosaurus, was as long as a whale, with conical teeth seven inches long, and as the portion of the jaw into which the teeth were set was three feet long, the head must have been of great size. The neck was of massive proportions, some of its vertebræ being eighteen inches in circumference, although only one inch long, thus uniting flexibility

with great strength. In place of legs and feet, the animal was provided with paddles for swimming, like the whale. Of several other genera, which more nearly resembled the crocodiles of the present epoch, the genus cetiosaurus was also remarkable for its great size, the larger species having attained the length of sixty feet. This was also an aquatic genus, a broad vertical tail having been the main organ of motion. It was also provided with large webbed feet.

There were other saurians of terrestrial habits, allied to the iguanodon. The megalosaurus had strong two-edged teeth curved backwards and tapering to a sharp point, and with both edges serrated (notched like a saw). They were therefore admirably adapted for holding, tearing and cutting up their prey. It was probably about thirty feet long, and, like the iguanodon, was elevated several feet from the ground by massive legs, and had a body much broader and deeper than the modern saurians. These with the numerous marine reptiles

> "Formed a group of predatory animals never surpassed in fierceness, strength, and veracity." (Ansted).

But the most extraordinary of the reptiles of that period was the pterodactyle, an animal with the form and general appearance of a bat, except in the head, which was very long and resembled that of a crocodile, to which also the internal anatomy of the body corresponded. Although the neck contained only seven vertebræ, it had great flexibility, and the head could be thrown over so as to rest on the lower part of the back. The apparatus for flying in bats consists of an enormous extension of four of the toes with the skin stretched across. But in this animal the fifth toes only were greatly elongated, and the skin was extended from these along the sides of the legs and body. The other toes being free, the animal could walk or swim with the wings folded.

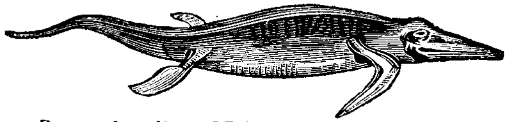
This interesting group of strata is also remarkable for containing the remains (in the Stonesfield slate) of the first mammals known to have existed. They belonged to two extinct genera of marsupials.

LIAS SYSTEM.

The strata of this system consist chiefly of calcareous and argillaceous matter more or less mixed. It is probably richer in organic remains than any other formation.

In the absence of corals, the sea abounded in echinodermata, among which were most conspicuous the crinoideans. One of the genera of this order, pentacrinites, had a five-sided stem, from the summit of which the arms were given off in innumerable ramifications. The whole number of pieces in one of these animals has been estimated at 150,000. Fossil shells also were very numerous, especially ammonites, of which sixty-nine species are found in the British Lias. Fishes were also found. But this also, like the oölitic, was an age of gigantic reptiles, the most extraordinary and most common of which were the numerous species of the marine genera Ichthyosaurus and Plesiosaurus.

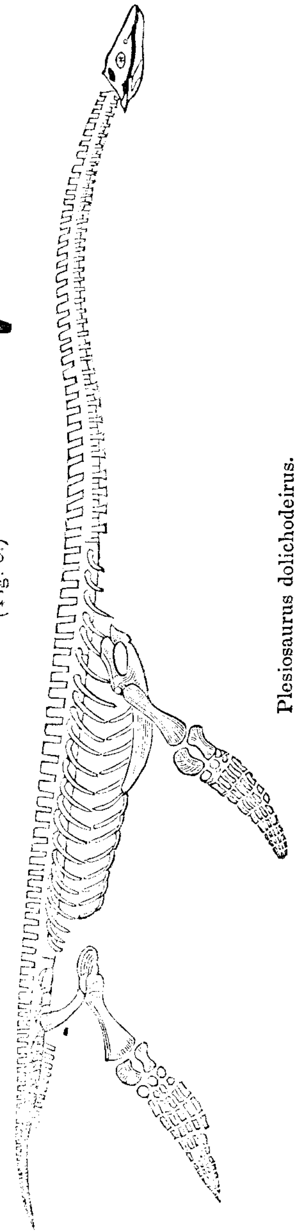
(Fig. 7.)



Restored outline of Ichthyosaurus communis.

The Ichthyosaurus (fish lizard) had some external resemblance to a fish but a much longer head, a smooth wrinkled skin like a whale, with a large and powerful tail expanded vertically like the caudal fin of a fish. The jaws were of great size, with an opening of seven feet, armed with a row of long sharp conical teeth, of which the number in some individuals was upwards of one hundred and eighty. The eyes were much larger than those of any other known animal, being eighteen inches in the diameter of the orbit, with the power of greatly varying the focus of vision, and the quantity of light received, so as distinctly to perceive objects near or remote, and by day or by night, or in the obscurity of the depths of the ocean. Instead of feet, it was furnished with long paddles of great flexibility, which contained in some individuals two hundred bones, and which were furnished posteriorly with long fins like those of sharks. The body was of great size, being chiefly filled with a stomach which was in proportion to the mouth. In it have been found the

(Fig. 8.)



Plesiosaurus dolichodeirus.

half digested fragments of fishes and other huge reptiles. So numerous and voracious were these animals, that their coprolites (fossil excrements) form strata in England of many miles in extent.

The Plesiosaurus had a smaller wedge-shaped head, a neck of extraordinary length, flexibility and strength, and paddles not inferior in power to the Ichthyosaurus, while the body was comparatively small and slender, its length being about seventeen feet. With the power of creeping on land, it possessed extraordinary powers of swimming which enabled it with ease to overtake its prey, while the powerful and rapid motions of its wedged-shaped head, wielded by its long and flexible neck, rendered it a match for most of its enemies, except the more powerful Ichthyosaurus.

TRIASSIC SYSTEM.

This system is the most recent among those that are older than the cretaceous which are found in this country. The strata consists chiefly of sandstones and conglomerates, with some limestones, and often contain deposits of salt and gypsum. Being a marine deposit, the vegetable remains are less numerous than in the coal measures. Although the plants have some general resemblance to the coal plants, geologists do not look for beds of true coal in this formation. In the Muschelkalk are the remains of crinoideans, of molluscs, which are mostly of genera inhabiting shallow water, and of numerous fishes.

It was in this period that reptiles first had that enormous developement of size and number, which renders the secondary periods the most interesting of the geological series. Large marine saurians and tortoises were common in this epoch, but the most extraordinary was the labyrinthodon, intermediate between the frog and the crocodile, but as large as an ox. Not only many of the bones, but the foot-prints of this animal are perfectly preserved, shewing in the foot a singular resemblance to the human hand.

But the most interesting and remarkable remains of this period are the foot prints of enormous birds and of other animals, in the sandstone of the valley of the Connecticut river in Massachusetts and Connecticut. These had been noticed by a few persons for several years previous to the geological survey of that State, and were called turkey tracks. But Dr. Deane of Greenfield, who has since investigated them with success, having called the attention of President Hitchcock to some of these 'turkey tracks,' the latter gentleman commenced a series of investigations which resulted in conclusions so contrary, as was then supposed, to the general analogies of the organic nature of this period, that it was a long time before they obtained general credence, Reptiles were the highest order of animals before supposed to have existed at this early period, but from the discoveries of President Hitchcock, it appears that birds, which perhaps had some affinities to the class of reptiles, were common, and that there were many species, and some of gigantic size, surpassing the famous Dinornis of New Zealand. The feet of some were sixteen to eighteen inches in length, with the toes as large round as a man's wrist, and the stride of the animal was four to six feet. Other tracks are less than the foot of the humming bird, although these are probably the young of a species which may have been as large as a sparrow. Dr. Deane has recently found the tracks of unknown and strange quadrupeds associated with the bird tracks. Even the impressions of rain drops are preserved, whose slanting direction records with infallible accuracy the direction of the wind in a passing shower.

PERMIAN SYSTEM.

"The Permian rocks consist of distinct strata of very varied lithological character. They are composed, for the most part, of white limestome with gypsum and rock salt, of red and green gritstones, with shells and occasionally with copper ore, and of magnesian limestones, conglomerates, &c. The whole series is highly fossiliferous, and contains the remains of extinct species of animals and vegetables, greatly resembling those of the carboniferous period."—*Ansted.*

In the magnesian limestone, reptiles appear, which are not unlike the lizards of the present day. With the exception perhaps of the footmarks in the carboniferous system, they are the oldest remains of warm-blooded animals that have been found.

CARBONIFEROUS SYSTEM.

This system is one of the most interesting in an economical and scientific point of view. It is the great repository of coal. Probably all the valuable beds of fossil fuel belong to this system, and the expectations which may be entertained of discovering it in profitable quantities in other rocks, are likely to prove groundless, as they certainly have hitherto. The strata consist of sandstone, shales, and limestone, with beds of coal, which latter are in some cases thirty feet thick. The valuable beds repose upon a bed of underclay which abounds with the singular fossil roots called stigmaria, whose trunks called sigillaria are also found in the coal fields.

"So thoroughly is the Welsh miner persuaded that the two things (the coal seam and underclay) are essentially conjoined, that he would as soon expect to live in a house without a foundation, as to work in a coal seam which did not rest upon underclay." "This fossil (stigmaria ficoides) so completely fills every bed of underclay, that it is not possible to cut a cubic foot which does not contain some portion of the plant."—*Logan.*

The coal itself is fully ascertained by microscopic examination of its structure to have been of vegetable origin. Usually the roofs of the coal mines abound with ferns and many other plants, which are preserved in the beauty and delicacy of their forms with great perfection. Dr. Buckland remarks of a mine in Bohemia,

"The roof is covered with a canopy of gorgeous tapestry, enriched with festoons of most graceful foliage, flung in wild and irregular profusion over every portion of its surface. The effect is heightened by the contrast of the coal-black color of these vegetables, with the light ground-work of the rock to which they are attached. The spectator feels himself transported, as if by enchantment, into the forest of another world; he beholds trees of forms and characters now unknown upon the surface of the earth, presented to his senses almost in the beauty and vigor of their primal life; their scaly stems, and bending branches, with their delicate apparatus, of foliage, are all spread before him, little impaired by the countless ages, and bearing faithful record of extinct systems of vegetation."—*Buckland.*

Nor was animal life less prolific in the period of the carboniferous limestone. The great mass of the mountain limestone of Europe was formed in the ocean, by the coraliferous tribes. The crinoideans and shells of curious structure were abundant. The relics of one hundred andtwenty species of fishes have been found.

OLD RED OR DEVONIAN SYSTEM.

The formations of this system consist of conglomerate, sandstones and slates of great thickness, with limestones. Some thick deposits of limestone are the remains of ancient coral reefs. Crinoideans and shells were abundant. The remains of about fifty species of fishes have been described, and, like all the others of the palaeozoic periods, belong to the order of ganoideans.

NEW YORK OR SILUREAN SYSTEM.

This system, comprising about thirty formations, is most fully developed in New York. By the geologists of that State it has been subdivided into four divisions, which, as well as the formations, have received names from the places in which they are most exhibited. These divisions are founded partly on geographical considerations, and are subject probably to some modification.

The Erie division consists of slates and sandstones, with a few thin beds of limestone. They contain some plants not unlike the coal plants, with numerous shells and trilobites. The latter were a tribe of crustaceans, whose remains were found in great numbers in the older and middle palaeozoic periods, but which then became extinct.

The Helderberg series abounds in valuable limestones, with some shales and sandstones. It is rich in gypsum, and salt. Shells and coral were abundant in this period. A few remains of fishes also occur.

The Ontario division consists of conglomerates, sandstones and limestones. The limestone of Niagara Falls belongs to this division, and abounds with corals, shells, and other interesting fossils.

The Champlain division consists of limestones, slates and sandstones, and with the exception of the lowest formation, the Potsdam sandstone, is fully developed in Western Vermont. Shells, corals and trilobites were abundant in this period.

TACONIC SYSTEM.

The formations of this system consist of limestones, slates and conglomerates. They are supposed by some geologists to be only a part of the New York system altered by the action of heat. Others again regard them as a distinct and older system. As these rocks are so fully developed in this State, and the origin of them is yet in doubt, we shall reserve a statement of the facts for the Final Report.

If they are identical with the New York rocks, we have in the Potsdam sandstone, the palaeozoic base, or the remains of the first organic beings known to have existed on the earth. It is remarkable that these are shells, although we should have expected to find the remains of plants, since the animal is dependent on the vegetable kingdom for nourishment. If the taconic rocks are more ancient, the palaeozoic base is carried further down, but the most ancient organic remains are here also marine animals.

PRIMARY STRATA..

Beneath the oldest fossiliferous rocks lie certain highly crystalline strata, which have been subjected to intense, and for the most part, long continued heat. They are much disturbed from their original position, and have been thrown into a confused arrangement. They are gniess, mica slate, and some limestones. From the absence of fossils, it has been supposed that they were deposited before the existence of organic beings, and thus that they indicated a commencement of at least one great series of creations of organic life. Yet since they have been intensely heated, it is obvious that organic forms *may* have once been embedded within them, and consequently no inference respecting

the condition of the crust of the earth during this period can be made with confidence. The non-existence of organic life can only be inferred from strata of very mechanical structure, destitute of fossils, and generally distributed beneath the fossiliferous rocks. It is unnecessary to say that such rocks do not exist, and as astronomy shows that we are within an assemblage of celestial orbs, whose limits, in regions too distant for imagination to conceive, we cannot find, so geology shews us to be on a stream of time, whose course it traces through inconceivable myriads of ages past, but whose source and termination are far removed from our knowledge, to where time merges into eternity.

But not only is the history of the primary rocks obscure ; it is often impossible to determine which of the crystalline strata are primary, and which of them are of palaeozoic age, but have since been altered by igneous agency. Many of this latter origin are known in Europe, which were once supposed to be primary, but are now known to have originated in some much later geological periods. Thus the history of all those rocks, which cannot be distinctly traced beneath the oldest palaeozoic strata, is enveloped in obscurity. Here all the sources of knowledge,—relative position, fossils, and original mineral constitution,—fail the geologist whose lot is cast in such a region. Such is most of Vermont.

Duration of Genera, &c.

We had occasion to remark on the duration of species, and we might, in noticing the organic remains of the several systems, have considered the *duration* of *genera*, and of the more comprehensive groups, had our limits permitted. We select now a few striking examples. Of the chambered shells, there are known to have existed in the palaeozoic and secondary periods, upwards of six hundred species of a dozen genera, of which there remained after the secondary periods, only one genus, the Nautilus, which has existed through all the systems, and which contained, in the tertiary epochs, four species, and in the present it contains only two.* To this only one genus of chambered shells with one species† has been added. On the other hand, of the convoluta, a family of shells containing about seven hundred species of six genera, many of which species are among the most abundant as well as beautiful of any now living, none existed anterior to the tertiary epochs. But some tropical genera, as the Lingula, have existed from the earliest age to the present.

The genus cerithium is not known to have existed before the tertiary period, yet two hundred and twenty species have been found in the tertiary strata, and more than one hundred belong

* Nautilus pompilius and N. umbilicatus. † Spirula Peronii.

to the existing fauna. No general rule, it would seem, can be laid down for the duration of the groups more comprehensive than species. Some are represented by a few species in all the systems, or in a few of them, and others by many species in a few formations. It may however be said of most of those genera, which have survived through all the periods, that they either belong exclusively to tropical climates, or inhabit deep waters.

Connection of Geology with the Bible.

As many well-meaning persons are disturbed by a supposed incongruity between the principles of geology and the Mosaic narrative, a due respect to such requires a few words on this subject. It should be remembered, that the design of the bible is not to teach science, and that the object of the narrative of the creation, in the bible, was simply to teach the religious truth, that there is One God, the Creator of all things, and not to anticipate the developments of geology. As a necessary consequence, the common language of that day, was used on subjects belonging to science, for,

"What other language would have been consistent with Divine wisdom? The inspired writers must have borrowed their terminology either from the mistaken philosophy [of other nations] of their own times, and so have sanctified and perpetrated falsehood, unintelligible meantime to all but one in ten thousand; or they must have anticipated the terminology of the true system without any revelation of the system itself, and so have become unintelligible to all men; or lastly they must have revealed the system itself, and thus have left nothing for the exercise, development, or reward of the human understanding, instead of teaching that moral knowledge, and enforcing those social and civic virtues, out of which the arts and sciences will spring up in due time, and of their own accord." (*Coleridge*, Lit. Remains.)

All therefore that can reasonably be expected on this subject in a Divine Revelation, is, that it should not expressly teach a system inconsistent with true science.

But it is supposed by some, that the bible teaches that the materials of the earth are no older than the human race, and such a doctrine if really existing in any portion of the bible, would be fatal to its authenticity. Not only geologists, however, but many theologians, who wrote before the discoveries of geology, have been of the opinion that the time of "the beginning" is not fixed. Let any one, who is perplexed on this subject, re-examine the first verses of Genesis, and see whether any thing is said of the length of time, during which "the earth was without form and void," and whether there is any expression of time before the first day's work. Surely, it would have been as much out of place for Moses to have given a description of the extinct races, which existed before "the first day," as it is unreasonable to draw any conclusion, from his silence, unfavorable to the credibility of the sacred narrative. How the account of the six days is to be interpreted, is a question for biblical critics, with which geology has no concern, and the supposed analogy, between those days and the geological periods, will be found to vanish on strict examination. For the satisfaction of some, however, we add the interpretation of a venerable English divine, of great learning and piety, Dr. John Pye Smith.

"1. The first verse of Genesis describes the creation of the matter of the whole universe, probably in the state of mere elements, at some indefinite epoch in past eternity. 2. The term earth, as used in the subsequent verses of Genesis, describing the work of six days, was designed to express the part of our world which God was adapting for the dwelling of man and the animals connected with him. 3. The narrative of the six days' work is a description in expressions adapted to the ideas and capacities of mankind in the earliest ages, of a series of operations, by which the Being of omnipotent wisdom and goodness, adjusted and finished, not the earth generally, but as the particular subject under consideration here, a PORTION of its surface for most glorious purposes. This portion of the earth I conceive to have been a large part of Asia lying between the Caucasian ridge, the Caspian sea, and Tartary, on the north, the Persian and Indian seas on the south, and the high mountain ridges which run at considerable distances, on the eastern and western flank. 4. This region was first, by atmospheric and geological causes of previous operation under the will of the Almighty, brought into a condition of superficial ruin, or some kind of general disorder. Probably by volcanic agency it was submerged, covered with fogs and clouds, and subsequently elevated, and the atmosphere by the fourth day rendered pellucid. 5. The sun, moon, and stars were not created on the fourth day; but then made, constituted, appointed to be luminaries."

Again, geology gives us no evidence of a universal deluge since the commencement of the historical period, nor of any other deluge which was universal, and throws great doubt on any such theory. Yet many persons, not considering what meaning was attached by the Jews to the general expressions of the bible respecting the earth and mankind, and how absurd it is to suppose that they were told that America, and New Holland, and central Africa were covered with a deluge, and their inhabitants exterminated, are much disturbed on finding their favorite theories untenable. Yet such theories make no part of the bible. We again quote Dr. Smith:

"The Noachian deluge was limited to that part of the world occupied by the human race, and therefore we ought not to expect that any traces of it on the globe can now be distinguished from those of previous and analogous deluges."

Many also suppose that death was not introduced into the course of nature, until after the guilt of human sin. Yet countless multitudes perished during the long periods anterior to this event, not only by the decay of old age, but as a prey to the myriads of ferocious animals with which the land and water were infested. Perhaps if it be considered that the Supreme Being, having infinite intelligence and wisdom, must have foreknown the existence of moral evil, and have therefore, from the beginning, arranged his plans with reference to it, it may be admitted still, that even the physical death of the brute creation was the consequence of human sins, without any discrepancy with the facts of geology.

On the other hand, it must be regarded as an interesting fact, that when geology and the bible both treat of the same subject, they do really agree; viz. in reference to the length of time during which man and the animals, in which he has an interest, have existed. Although the geologist cannot measure time by years, yet as near as computation can be made, the geological period coincides with that which is assigned in the sacred scriptures.

PART II.

MINERALOGY.

We have introduced this head here, rather because it forms a part of our general plan, than because we are now prepared to offer any connected statement of results. We have before remarked upon our progress and disappointment in this department of the survey. A catalogue, made some time since, of all the published articles accessible here, and of some in manuscript, relating to the minerals of Vermont, shews that much time has in former years been given to the minerals of Vermont by numerous observers, and expectations probably higher than the facts, and certainly than the results of the survey will warrant, have been entertained by some respecting the interesting minerals of Vermont.

Although metamorphic rocks are by no means destitute of interesting mineral localities, those which are of igneous origin are far more likely to reward the collector with their rich and various contents. Not more than one-twentieth of the State consists of igneous rocks, but seven-eighths of these are metamorphic, and we have accordingly a due proportion of minerals. Many of the localities are well known, and we add only a few as they occur to us, which we have lately noticed, in addition to those which, being also of economical interest, are mentioned in another place.

In the north west corner of BETHEL is a bed of fine whitish talc, most of which is more or less densely filled with elegant crystals of actinolite, many of which are large, and the specimens exhibit them of all sizes, with all degrees of aggregation. At the same locality, chlorite occurs in large quantity with octahedral iron ore sparsely disseminated. These minerals constitute a bed about four feet thick, not far west from the east boundary of the talcose and chlorite slates. A portion of this bed of talc is free from other minerals.

In the south east corner of THETFORD, kyanite is rather common, in the conformable white quartz veins of segregation in the mica slate. We did not find any specimens of great beauty.

In BROOKFIELD, within a few rods of the north east corner of Braintree, mispickel occurs abundantly.

Black mica, wrinkled and nearly pure, occurs in the naked mountain, south east of the village in TOWNSHEND.

In CABOT, one and a half miles from the south line, on the main road to the village, staurotide is abundant in mica slate, and many of the crystals contain small garnets imbedded. Some of the rocks here contain large imperfect crystals of hornblende very thickly disseminated in a base of compact hornblende strata, and the more rapid decay of the base leaves the crystals in bold relief, giving to the rock a remarkable appearance.

Magnificent specimens of spherical concretions of black mica, mostly one to one and a half inches in diameter constitute large portions of a few blocks of granite found in WATERFORD and RYEGATE. These specimens even much exceed in beauty those of the well known locality in CRAFTSBURY. At the latter locality however they fill enormous blocks of granite, which are thickly scattered over several acres near the lower village, south east from the centre of the town.

We have frequently been solicited to furnish specimens of the Middlebury zircon, and we take this opportunity to say, that it was found only in one boulder of syenite, and that, with the exception of two specimens in the cabinet at Middlebury college, it was all taken away many years since.

Elegant crystals of titanium, from one five-hundreth to one one-hundreth 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, and we have a similar specimen from WAITSFIELD. The cyrstals in these specimens are nearly of a silver white with a faint tinge of yellow. Larger crystals occur in limpid quartz, and of the usual copper-red color, in ROCHESTER, at a locality which is kept secret by two individuals acquainted with it.

PART III.

CONCRETIONS.

Although the phenomena of concretion have attracted more or less attention from many naturalists, they do not, so far as we are aware, appear to have been collected together and examined as a distinct subject. Their grand and extraordinary features, in the prismatic columns of basalt and of greenstone, have indeed been observed both by popular and scientific writers, and the cause of the prismatic form has been shewn by actual experiment. The calcareous concretions of the magnesian limestone in Durham, (England,) and the oölitic structure of this rock in the southern part of Yorkshire have been described by geologists, while other immense accumulations of small concretions are well known to constitute a considerable part of the oölitic rocks of England. The remarkable forms assumed by the argillo-calcareous concretions of clay beds have not been unnoticed. In Great Britain they have been supposed, even by some geologists, to be artificial products. They have been noticed in Sweden, and have been supposed to be the fossil remains of mollusca. Others are of the opinion that they are concretions. In this country, especially in New England, they are very common. But little attention, however, has been given to them, except by President Hitchcock, who, in his Final Report on the Geology of Massachusetts, has given an interesting chapter on their constitution, properties, and forms, with some suggestions on the power of concretion, but without arriving at any conclusions respecting its nature.

Limited not only in time but by other incidental considerations, we can offer merely a brief and very imperfect synopsis of this subject.

The Power of Concretion.

Two things are necessary to define the power of concretion,—the law of its attraction, and the kinds of particles which are subject to it. Thus the law of crystalization is defined by its building up in certain geometrical forms particles which are homogeneous. Cohesion is commonly understood as the power which unites homogeneous or heterogeneous particles without any definite forms and without change of properties; and chemical affinity unites heterogeneous particles with a change of properties into more complex homogeneous particles, which then obey cohesion.

Law of Concretion.

This is molecular attraction in the direction of the radii of a sphere towards the centre.

The proof of this proposition rests on the subordinate proposition, that concretionary forms are either perfect spheres, or spheres modified by circumstances. For the force must obviously be exerted along or towards the radii, otherwise the resulting form would not be spherical; it cannot be outwards, for this would be repulsion not attraction; it cannot normally be towards successive points along a few radii, from the intervening spaces, for then we should have a divergent columnar as well as concentric structure, such in fact as we find in globular aggregations of imperfect crystals, which result from the combined action of crystalization and concretion, and consequently are neither perfect cyrstals nor perfect concretions; the concretionary attraction therefore must be towards the centre. Accordingly when there is a deficiency, in argillo-calcareous concretions, of the carbonate of lime, which appears to be most subject to this power, the exterior parts of the concretion are less firmly concreted and contain less carbonate of lime.

Our subordinate proposition, being merely a generalization, requires the consideration of the particulars generalized, which we must briefly notice, reserving the more detailed examination of the facts for some future occasion.

Spheres with little or no modification do actually exist in immense numbers, and are probably far more numerous than perfect crystals. Every geologist will at once call to mind the vast deposits in England with an oölitic structure. This structure also exists in some Tertiary and carboniferous strata, and even in the Isle la Motte limestone of New York and of the Isle la Motte. Such are also many of the concretions in the magnesian limestone of Durham before referred to. Occasionally also perfect sheres are found in concretionary greenstone, as at Mt. Holyoke, in Massachusetts, and in some dykes in Vermont.

The modified, or if we may so speak, the secondary forms no less confirm the general proposition, since these forms may be shewn to be spheres, modified by circumstances which are known to exist.

The prismatic forms of trap rock result from the lateral interference of distinct spheres. It is well known that Mr. Gregory Watt fused 700 pounds of basalt; portions which cooled rapidly were amorphous and vitreous, but a slower process resulted in the formation of spherical masses, which increasing appeared to press upon each other, and being free above in the air and below in the liquid mass, were lengthened perpendicularly into prisms. If a lateral pressure actually exists between the spheres, it may easily be demonstrated, (since six equal continuous circles may be drawn in contact, touching an interior equal circle,) that in the case of equal spheres with equal lateral pressure, regular hexagonal prisms will result, and that with unequal spheres or unequal pressure other prisms will be formed, the number and dimensions of the sides of which would vary accordingly.

But the lateral pressure, if it exist at all, is far from being the only circumstance to be considered. When the spheres are in contact, there are no more particles at the point of contact in the line of attraction, and this point is therefore a part of the resulting surface of the prism; but the particles around would still continue to arrange themselves in obedience to the same law, and opposite concentric circles of particles around the first point of contact would successively come in contact face to face, until those on the adjacent sides of a given prism also should touch each other in the same horizontal plane, and these points of contact will then be extended up and down, forming the lateral edges of the resulting prisms, in the same manner as the first contact resulted in the lateral faces.

But it must still be considered, how it is that the prisms are continued to so great a length as at the Giant's Causeway; for if spheres are produced in various strata of the fused mass, it could not be expected that the perpendicular axes of the several spheres should coincide in straight lines, nor that the horizontal joints should be spherical, and the lateral ones, plane surfaces. But if we suppose the surface of the cooling mass to produce a stratum of spheres first, and that concretion takes place deeper and deeper with a gradual and uninterrupted process of cooling, it is easy to see how prisms may commence at the surface, and be gradually prolonged downwards. It is not however of course necessary that the surface should be horizontal, as imperfect fluidity and containing walls of crust, and other circumstances, may give an inclined cooling surface. Not a few of the examples of columnar basalt are known to be inclined, and some are even horizontal.

That the various irregular forms of the trap rocks are more common than regular prisms, is an obvious result of variations in the circumstances which have been considered.

Let us now consider the case of the argillo-calcareous concre-

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tions (claystones,) which are formed in clay deposits. Leaving out of view other circumstances, we find them formed in various laminae of clay at a greater or less depth beneath the surface, but each single concretion usually in a given lamina, although those of different laminae sometimes coalesce. The most obvious and common modification in such circumstances is that of spheroidal forms, flattened and extended equally or unequally in different directions in a horizontal plane, and of course orbicular, ellipsoidal, oval, &c. Two causes exist which may occasion these depressed forms; the division of the general medium of clay into laminae, may interpose an obstacle to a corpuscular attraction, and prevent the free and ordinary passage of particles from one lamina to another; or, as gravitation modifies the action of low degrees of chemical affinity, so the perpendicular downward pressure in clay beds, which must greatly exceed the pressure in other directions, may cause an attraction, which has no great intensity, to act with more efficiency in horizontal directions.

The magnesian limestone of Durham, (England), above mentioned, contains discoid forms made up of circular laminae running into each other, which

"Indicate a tendency to aggregation about different centres, even when, owing to some cause, the operation could not develop itself in a vertical direction."—*Ansted.*

The influence of nuclei is well known. Thus when the rootlets of plants penetrate the clay beds, cylindrical concretions are made about them. In this case the filament appears to be an axis of attraction; but an axis may be regarded as composed of an indefinite number of points which are centres, and the cylindrical concretions consequently as composed of an indefinite number of spheres, which have coalesced by their upper and under surfaces.

The attachment of the nucleus to some point of support modifies the form. Thus forms which otherwise would be spherical become hemispherical, and mammillary if confluent. An interesting example, of calcareous concretions thus modified, is described by Mr. Lyell, as existing in the tufaceous deposits of Tivoli.

We have of course considered in these remarks chiefly those forms, which are really or apparently simple. The complex forms result from the coalescence of those which are simple,and the study of them, although interesting, is, like that of the aggregation of imperfect crystals, comparatively unfruitful in general results.

In coming to the conclusion that the normal form is a sphere, we do not put forth for this theory the claim of novelty, which might be a doubtful recommendation. In enumerating six predominant forms in the claystones of Massachusetts, commencing with the sphere, President Hitchcock remarks, that "nearly all of them might be regarded as modifications of the first."

If the law above proposed be regarded as established, a theory of it may be required. This however would render it necessary to have previously determined, whether the power of concretion be distinct from that of cohesion, a question on which we have at present only suggestions to offer.

The other fundamental question, respecting the power of concretion, relates to the substances which are subject to it. This question is yet involved in much obscurity, for the observations and analyses of concretions are not sufficiently numerous to furnish the required data. The substances seem to belong for the most part to two classes; any rocks of igneous origin, for it has been exerted in granite and in syenite as well as in trap rocks; and calcareous substances of aqueous origin. There are also ferruginous and manganesian concretions. In the case of the igneous rocks, the power is not restricted to a simple mineral, but the mixed ingredients of the mass of rock are, apparently at least, alike subject to the law. In a large portion of the other cases which now occur to us, more or less of carbonate of lime is present.

An interesting fact is mentioned by Ansted, that the concretions in the magnesian limestone of Durham are themselves free from magnesia. President Hitchcock analysed a number of specimens of claystones in Massachusetts, and two specimens from Nykoping, Sweden, from which it appears that from forty to sixty per cent. were carbonate of lime, and the rest was mostly silica, alumina, and iron, but these were not separated. On the next page we give the more minute analyses of Mr. Olmsted, which in general correspond with those of President Hitchcock, but also shew the presence of protoxide of manganese; in both series of analyses, several specimens were found to contain a small portion of magnesia.

President Hitchcock infers that the claystones are not a definite compound of carbonate of lime and clay, which conclusion is further fortified by the analyses of Mr. Olmsted. Since the vast majority of perfect spherical concretions consist of nearly pure carbonate of lime, it may be inferred that the other ingredients of claystones should be regarded as foreign substances.

The wide difference, between the constitution of those concretions which are of igneous origin and those which are of aqueous origin, is truly remarkable,and seems to present an insurmountable obstacle to definite conclusions.

The following are the analyses made by Mr. Olmsted for this survey.

Localities.	Dummerston.	Addison.	Alburgh.	Pittsford.
Carbonate of lime.	51.08	45.09	53.17	42.88
" " magnesia.	5.40	17.34	2.48	3.76
Alumina.	28.40	21.13	20.95	19.10
Peroxide of iron.	8.12	1.73	6.76	8.81
Protoxide of manganese.	1.50	0.60	1.50	trace.
Silica.	8.08	16.18	12.40	25.99
Water.			3.48	
Total.	102.58	102.07	100.74	100.54

Localities.	Derby.	Shelburne.	Norwich.
Carbonate of lime.	49.66	52.58	44.84
" " magnesia.	1.59	5.31	3.26
Alumina.	12.60	7.30	8.50
Peroxide of iron.	8.68	3.02	5.32
Protoxide of manganese.	2.00	1.38	4.47
Silica.	16.18	28.70	29.08
Water.	9.32	1.71	4.53
Total.	100.00	100.00	100.00

Comparison of the power of concretion with that of crystalization.

The analogies between this power and that of chemical affinity are remote and of but little interest. President Hitchcock has remarked on some of its analogies with crystalization. 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 their concentric structure they have a cleavage, which, like that of crystals, is parallel to the surfaces 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 centres 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 claystones,

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 crystalization; 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 surface. May not the ordinary effects of cohesion be the results of concretion with an indefinite number of centres, 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 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, i. e. edgewise.
- 3. Dimera; composed of two simple or encyclic forms;
  - *a.* with concentric structure;
  - *b.* nuclear.
- 5. Decamera; with four to ten parts;
  - *a.* elongated, parts less confluent;
  - *b.* " " quite "
  - *c.* not " " less "
  - *d.* " " " quite "
- 6. 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 centres, must be rejected from such an arrangement.

Concretions in Vermont.

These are the trappean, which will be described in connection with the trap rocks on a future occasion; the micaceous, occurring in a peculiar variety of granite, before mentioned; those of manganesian wad; the silico-calcareous, which are also argillaceous, and occur near the junction of clay beds with overlying beds of fine sand; the argillo-calcareous, occurring in blue and

in brown clay; and the argillo-ferruginous, which are cylindrical, and occur in clay beds, with their longer axis perpendicular to the laminæ, through several of which they are prolonged. They are also occasionally found in other rocks, but in general such are of more irregular forms.

Localities of the cylindrical ferruginous concretions exist at Appletree Point, in Colchester, where they are, for this class of concretions, unusually hard; at Chimney Point, in Addison, &c.

Clay-stones occur in Rutland and Pittsford at several localities, in Brandon, Sudbury, Orwell, Addison, North Hero, and Alburgh in brown clay; and in Dummerston, two localities in Norwich, two in Ryegate, in Sharon, Bethel, Warren, Shelburne, Essex, Stow, and Derby, in blue clay.

At most of these localities the varieties of form are very remarkable and numerous, and the details which have been and will be noticed are too voluminous for an annual report. Even in a collection of several hundred from a single locality, it is difficult to find duplicates of a given variety.

PART IV.

SCIENTIFIC GEOLOGY.

"What struck me most in England was the perception that only those works that have a practical tendency awake attention, and command respect, while the purely scientific, which possess far greater merit, are almost unknown. And yet the latter are the proper and true source from which the others flow. Practice alone can never lead to the discovery of a truth or a principle. In Germany, it is quite the contrary. Here, in the eyes of scientific men, no value, or at least but a trifling one, is placed on the practical results. The enrichment of science is alone considered worthy of attention. I do not mean to say that this is better; for both nations the golden medium would be a real good fortune." (Liebig.)

"For one mind willing or capable of patiently working out and discovering a new truth or principle, there are hundreds who can apply to practice these principles, when once ascertained. Nothing can be more short sighted, therefore, even on pure utilitarian grounds, than the usual policy of the herd of cui bono philosophers, who award higher honors and emoluments to the application than to the discovery of scientific principles." (Lyell)

GEOLOGY OF VERMONT.

Although the sciences which *describe* the animal, the vegetable, and the mineral kingdoms of nature are therefore called Natural *History*, from the original signification of the word, yet in the proper English sense of history, geology is the only department of natural science which can be said to be historical. Beginning in the process of investigation, with the careful observations of the existing facts in the structure of the earth, it ascends by cautious inferences, from these effects of causes which have been in action in all periods of time, to a description, in chronological order, of the events which have occurred in the physical history of the earth.

The geological history of Vermont is conveniently divided into three great periods, of which the last is the *quaternary*, which includes the history of all the unconsolidated materials, the gravel, clay, sand, alluvium, &c. which cover the solid rocks.

The next preceding period embraces by far the greater and

most interesting portion of the geological history of the earth, and is represented in other countries by a long list of formations from the tertiary down to the older palaeozoic. The entire absence of any deposits in Vermont, which can be referred to this period, renders it impossible to give its history. Certain eruptions of trap and porphyry are the only events of which any relics are left. The third is the palaeozoic period, the most ancient portion of which is commemorated in the six fossiliferous formations of the Champlain rocks.

Unfortunately for the geological history of this State, a greater part of it consists of rocks which are destitute of fossils, which have been so disturbed from their original position and worn down, that their original order of position is rather a matter of conjecture, or at least of inference, than of observation, and whose highly crystalline structure, and in many parts, mountain masses and ramifying veins of granite, indicate the intense heat by which they have been metamorphosed. When these rocks were deposited—whether any or all of them were ever replete with fossils—when the granite eruptions burst through them with their intense igneous crystalizing agency—and when they were plicated into long mountain ridges—are, and are likely long to remain, matters of conjecture. To describe these as they now exist is therefore all that can reasonably be required.

QUATERNARY SYSTEM.

The absence of tertiary and secondary deposits is, in a measure, compensated by a very full development of most of the formations of this system. Commencing with the more ancient of them, they are the drift, the older pleistocene, the newer pleistocene, and those of the historical period.

DRIFT.

General distribution of drift. The description of the lithological characters of drift on pp. 91, 92, is strictly applicable to the drift of this state. In the lower parts of the valley of Lake Champlain it is mostly covered by the beds of clay and sand of the subsequent pleistocene periods: but on penetrating them, drift is usually found beneath. Examples, however, are not infrequent of clay reposing directly on the solid rock. With these few circumscribed exceptions, most common in the lowest parts, and the usual scattered spots of naked rocks, the State is entirely covered with drift.

The greatest accumulations are in narrow mountain valleys, and over the lower parts of the Green Mountain range. In no situations are the solid rocks so uniformly concealed for many miles in succession, as along the highest portion of the roads from Bennington to Brattleboro', from Manchester through Peru and Londonderry, from Rutland to Sherburne, and from Middlebury to Hancock. On these routes the drift appears most abundant at elevations of 1500 to 2000 feet, and is quite uniformly spread over the surface.

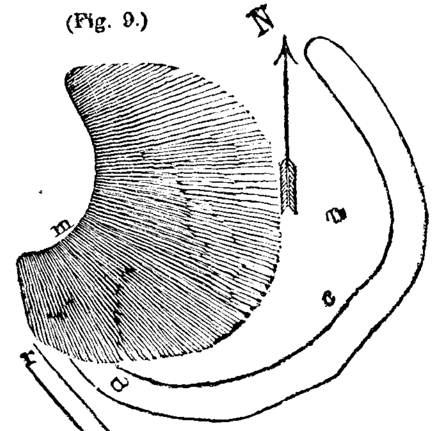
Drift moraines. Although a moraine is properly an accumulation of gravel and stones made by the agency of a glacier, the term may be extended to somewhat similar accumulations, which may have had a different origin. They are abundant, and many are of great magnitude, in mountain valleys and especially at the western foot of the Green Mountains. Those which are well rounded are more common than the elongated. They are, for the most part, composed of a loose mixture of small well rounded boulders, which seldom exceed six inches in diameter, and of gravel, pebbles and sand.

The most interesting examples occur in the valley between the Taconic and the Green Mountains. In and around the east village of Manchester they are very numerous. One of the most remarkable is half a mile southwest from the centre of this village, and although 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.

Extraordinary accumulations of similar moraines occur in this (Taconic) valley, at quite regular intervals of about five miles apart, viz. in East Manchester as above mentioned, half way between North Dorset and Danby, between Danby and the south village of Wallingford, and between the two villages of Wallingford. In the east part of Hinesburgh is a moraine about 3000 feet long and 2000 wide, and 300 feet high. In the south part of Lowell these moraines, although not of such extraordinary magnitude, fill the valley, and the materials are so slightly coherent that in dry weather some small streams lose themselves in the gravel.

A remarkable example occurs in a valley 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 south-west extremity of the moraine, which here joins the hills without any intervening depression, leading off on a level in the direction *a c*, and at *c* approaching nearer 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 boulders; *r* is the turnpike.

(Fig. 9.)



Moraine in Peru.

Dispersion of the drift. The direction appears to have been from between north and northwest to south and southeast. In tracing boulders to their parent ledges, examples may be found abundantly, although from the small angle between the general trend of the formations and the drift current, these facts do not appear on so large a scale as might have been, had the direction of the drift current and of the strata been transverse to each other. The fragments, for the most part, of one rock overlie the west margin of the rock which lies next to the east. But there are not wanting examples of rocks, which are not prolonged continuously through the length of the State, as the beautiful serpentine of Lowell, the boulders of which were carried abundantly in a direction about south southeast, over the summit of the mountain, which extends from about north northeast to south southwest, and is from 1200 to 1500 feet higher than the serpentine, In the east part of Enosburgh are scattered profusely fragments of a peculiar massive variety of the talcose slate, which contains, abundantly disseminated, small crystalline masses of epidote, a rock which is known to occur only in Berkshire a little west of the centre, indicating a direction to the southeast. Examples on the other hand occur which indicate a direction to the south.

The distances to which fragments have been transported is a matter of interest; the approach to coincidence, before noticed, in the direction of the ranges of the drift agency renders much caution requisite in drawing conclusions. An interrupted range of granite or serpentine is not unlikely to exist, beneath the superficial deposits, between a boulder in question and its nearest visible source. Yet after deducting all such uncertain cases, and those still more frequent, in which there is equal uncertainty from the north and south trend of the original ledge, very many remain of transportation of thirty and of forty miles, even of heavy iron ore. In general also it is true in this, as in the other neighboring States, that the larger fragments have been carried to a less distance.

This last remark, however, does not apply, in any considerable extent, to the great bulk of the drift, which consists of gravel and small pebbles mostly derived from rocks within a very few miles. The same is true also of a great majority of the superficial boulders, and the only exceptions which now occur to me are of districts in which the rock in place is far more perishable than the one lying next to the north.

In general there is a pretty close agreement between the durability of a rock, and the abundance of pebbles and boulders in distinction from the finer materials. I use the term durability, as including resistance both to chemical and to mechanical agencies. Some of our softest slates, impressible with the finger nail, still retain delicate drift scratches, and the smooth surface remains as it was, polished by the drift agency, although ever since exposed to atmospheric influences; but their fragments are not numerous. Limestone, being not only rather soft, but decaying also by solution, does not furnish its proportionate share of boulders. On the other hand the strip of quartz rock, on the west side of the southern half of the Green Mountains, equally annoys the traveller and the cultivator of the soil, if that may be called soil which consists mostly of pebbles and boulders, whose ellipsoidal form and more common size has procured the provincial appellation of "hardheads."

It is scarcely necessary to remark that the detachment of the fragments and rounding of their angles is not to be exclusively ascribed to the drift agency. The ordinary agencies of rivers and waves, and of the atmosphere are ever producing these results. If, as there is good reason to believe, Vermont was above the ocean during all or most of those periods, to which we have alluded as the dark ages in our geological history, some of these boulders and pebbles may have been worn by the waters of mesozoic and even of palaeozoic times. The accumulation of the materials may have been in progress during all the intervening periods, and since the lapse of time would alike accumulate the durable and consume the more perishable boulders, we find in this the cause of this disproportion in comparison with the extent of the parent rocks, as well as in the long continued violence of the drift agency itself.

In some places a part of the boulders are traceable to two sources, as in Middlebury, where are many from a variety of the red sandrock, which occurs ten miles to the north north-west, and

others are from another variety a few miles farther north in a due north direction.

FURROWS, SCRATCHES, AND ROUNDED AND POLISHED ROCKS.

On the general coincidence, usual elsewhere in drift regions, between the direction of the furrows and that of the transport of drift, we find no exception. From the facility and precision with which they may be measured, these scratches afford the best means of ascertaining the direction of the drift current.

Nearly two hundred examples, (reckoning as distinct cases those only which are at least one-quarter of a mile distant), have been found, and are particularly described in my journal. Among the districts most remarkable for their abundance, is the valley of the Winooski, especially the south side of the river from Richmond through Bolton and Duxbury. There the perfectly rounded surfaces of the talcose slate, the broad furrows, and delicate scratches, were protected by a fluviatile deposit of fine sand, during the long subsequent period of the older pleistocene, and therefore have a freshness which adds much to the beauty and interest of these results of the drift agency. Another region, surpassed by the former only in the interesting character of individual cases but not in their number, embraces the middle towns in Franklin county, and of the north part of Chittenden county, from Canada to the Winooski, where few ledges can be found which are not rounded and furrowed.

The limestone of Addison county abounds with well smoothed surfaces covered with scratches, which have been protected from decay by a covering of brown clay, and have within a few years been exposed by the removal of the clay in the gullies at the roadsides. On the other hand surfaces of limestone, which have been long exposed to atmospheric agencies,— the surfaces of rocks which are more or less feldspathic, as the granite and gneiss regions, and which decay by yielding up their potassa,—or surfaces which crumble by the admission of water into a porous or loosely laminated structure, seldom afford examples. Since, however, the deficiency occurs only in cases where the rock is undergoing disintegration, it would not perhaps be an unreasonable inference, that the entire surface of the rocky floor of the State was smoothed into cavities and convexities, and covered with furrows and scratches by the drift agency.

The greatest elevation at which drift furrows exist, is an interesting question, which has received some attention. They exist abundantly on Jay Peak, at the northern extremity of the Green Mountain range. This elevation was determined barometrically with a fine instrument of J. H. Temple, Boston, under very favorable circumstances, of a calm pleasant day between one and two o'clock, P. M., with simultaneous observations on a Bunten's instrument at the shore of Lake Champlain in Shelburne, and on a wheel barometer in Burlington. Taking the mean of the results, which differ only twenty feet, the height of the summit is 4025 feet above the ocean. The furrows were found a few yards east of the highest westerly point, and six or eight feet below it, and were continued over the east part of the Peak with a direction of north 40° west, as nearly as could be determined over a talcose slate which abounded with crystals of magnetic ore. Although from one to two inches wide and half an inch deep, their rough surfaces and the absence of small scratches indicate considerable decay of the surface. An immense number of fragments around the naked summit, with sharp angles and rough sides, shew also that there has been a powerful agency acting on this porous wrinkled slate, of frost and perhaps of lightning, since the furrows were made. Making, therefore, due allowance for the obliteration of the marks of drift agency, we can hardly avoid the conclusion, that such agency was nearly or quite as energetic as atl ower levels.

With the same object in view, an excursion was made to the White Hills of New Hampshire, in the hope, notwithstanding the feldspathic character of the rocks, that some furrows or at least boulders might be detected at a great elevation. President Hitchcock had before observed rounded rocks here, at an elevation of 5000 feet. (Elementary Geology, page 206, 3d edition.) The same example, probably, we saw, and found that, as is usually the case in Vermont, the northwest sides were rounded and the southeast uneven: at a little higher elevation to the north were distinct furrows with a north and south direction, which had been partly preserved by a vegetable deposit, and had been recently uncovered in making a bridle path. An example similar in all respects was found on the north side of Mount Pleasant, about 300 feet below the summit, an elevation rather less than the other.

The general direction of the drift agency, as indicated by the scratches, was from the north 10° to 20° west. In very numerous examples, not far from one third of the whole number, two or more distinct sets of striae may be recognised, with different directions, but those of each set are parallel. At Hill's quarry, in the Isle La Motte, there are eight sets, viz. north 8° east, north 3° east, north 10° west, north 25° west, north 43° west, north 45° west, north 47° west, and north 65° west. In general the striae of north about 10° west are most common, and then those which are north 20° to 30° west. It is not usual to find more than two or three sets, and it is probable, not to say certain, that the earlier striae were entirely obliterated by the long continued drift agency.

It is often possible to determine the relative age of the striae, although much caution is requisite. One which is shallow may appear to have been cut off by another which is narrow and deep, although the latter may be the oldest, and hence if the latter was in fact the more recent, the fact cannot be certainly inferred from such a case. If the striae are of nearly equal depth, it may not be possible to arrive at any conclusion. But when a small one is continued across the bottom of a somewhat deeper one, which often occurs when the latter is broader as compared with its depth, and if several such examples occur on a given surface, all tending to the same conclusion, there can be no reason for distrust. We have succeeded in this way, in about thirty examples, in determining the relative age of two sets of striæ, and find no exception to the general conclusion, that those which had the more westerly origin are the more recent. In one case, that of Hill's quarry above mentioned, the age of three sets was determined as follows, beginning with the oldest, north 10° west, north 8° east, north 47° west.

The parallelism of the striæ is one of the first characters to attract attention, and hence many persons, whose attention I have directed to them, have called them a *raking* of the surface. In surfaces which present the convexity of one-third or even of one-half of a sphere, there is scarcely any perceptible deviation from parallelism in the ascent of the scratches.

But although the minor inequalities of surface have not materially influenced the direction of the striæ, the general direction of the current was essentially modified by the prominent features of the surface of the State. In the valley of the Winooski, where it crosses the Green Mountain range, the direction of the striæ is generally from north 70° west to north 85° west. In the valley of the Lamoille where it crosses the same range, the direction is from north 75° west to north 85° west. The deflection on the summit of Jay Peak we have before noticed. A remarkable case of a deflection westward occurs in Putney, about three miles north of the village, where a valley opening to the west and south deflected the current, so that most of the striæ have a direction from north 45° east, and others are from north 25° east. But the usual course of the striæ varies from north and south, to north 15° west by south 15° east.

That these striæ and furrows belong to the same period with the drift, being indeed the effect of the transport of the latter, has been regarded as sufficiently proved by the coincidence of direction, and by the want of any deposits intervening between the striated rocks and overlying drift. It necessarily follows that they are as ancient as the drift accumulations. But our limestone districts afford abundant direct proof, that no considerable period elapsed between the termination of the striating agency, and the clay deposits of the older pleistocene, (themselves more recent than the drift,) which intervenes between them and the rocks where they occur in connection. For owing to atmospheric agencies, exposed surfaces of limestone have not retained the drift furrows, but wherever a surface has been recently uncovered, as by the gullies of roads, the most delicate striæ are found to have been preserved by a covering of a few inches in clay. It follows then, that the furrows and striæ could not have been exposed to atmospheric agencies, for a period which even human history would consider long, and as they could not have been submerged without the superposition of deposits, it follows, that the striæ which are covered by clay were made, at least in part, immediately before the deposition of the clay. It would not of course follow that the striating agency was limited to this point of time, which indicates its close only. But it is worthy of remark, that a period of violence appears to have been immediately succeeded by one as quiet, as could occur with existing agencies.

There is another class of examples of striated rocks, in which the rocks were covered with the fine sands of the older pleistocene, as is proved by the existence, on the hill sides above them, of river terraces which are composed of these sands, and by the sands around them. These terraces are, as we shall have occasion to notice more particularly in future, the relics of deposits made subsequently to the drift, and were afterwards, in consequence of the deepening of the channel of the river, cut away and borne down to a lower level. In the valley of the Winooski, the splendid examples of striated and polished rocks appear to owe their freshness to the fact, as before suggested, that they were thus covered during a great part of the time subsequent to the drift period.

Streams of stones.

The type of this class of phenomena was discovered in Richmond, Massachusetts, by President Hitchcock, and has since elicited much attention. Their characteristics seem to be, the arrangement in a line, of great length as compared with the breadth,—one, two or more miles long, to twenty to sixty rods wide,—of an enormous quantity of angular fragments of rock, overlying the common drift, and extending from a ledge of the same kind of rock in the direction of the drift current.

In the absence of any evidence of their overlying pleistocene deposits, the superposition on drift proves only that they were placed in their present position, at, or near the close of the drift period. It is not, however, to be inferred, that this kind of effect was peculiar to the close of the drift period, for whatever similar streams may have been strewed along previously in the period of drift agency, would subsequently have been either rearranged or buried beneath other drift, so as not now to be recognisable. For it is obvious that a stream of stones beneath the surface is not very likely to be discovered, and even those, which are on the surface, have been only very recently observed. A considerable portion of erratic blocks may have been removed from their previous situations in the same manner, not excepting even many, which, although well rounded, may have been worn by other agencies before the drift period. Proper streams, conforming to the type above referred to, must be difficult to recognise, not only because they must have been the last effects of the drift agency in order to their being undisturbed and visible, but many other conditions must conspire to furnish a satisfactory case. The ledge, from which they originated, must be recognisable without doubt from other rocks in the vicinity, and the rock must be one which does not rapidly decay by atmospheric agencies. They are also with much difficulty discovered and traced out, except in cleared land. We have nevertheless succeeded in tracing out one such phenomenon, and had it not been for dense and tangled forests, which required more time than could be allotted to them, probably other supposed examples might have been traced out satisfactorily.

A very interesting example occurs in Huntington, about two miles east of the village, and not far from the south-east corner of the town, on land of Mr. Bunyan Bradley, who mentioned the case as a curiosity, and suspecting its true character I have since examined it.

The accompanying figure (Fig. 10.) represents the prominent local features.

a h is a hill rising 150 feet above the valley *m n*, consisting of fine talcose slate, the direction of the laminae being north 15° east, with a dip 75° east. This hill is about one fourth of a mile long, with an average width of sixty rods in the northern half, and widening to the south.

g is a small hill of talcose slate with the same characters and position.

b c d h is a precipice, low at *b* and accessible, highest from *c* to *d* with a broken slope, which at *c* averages 40°, and 30° at *d*.

s y is a long narrow mass of very coarse binary syenite, included between the talcose slate on either side, nearly half way up the hill.

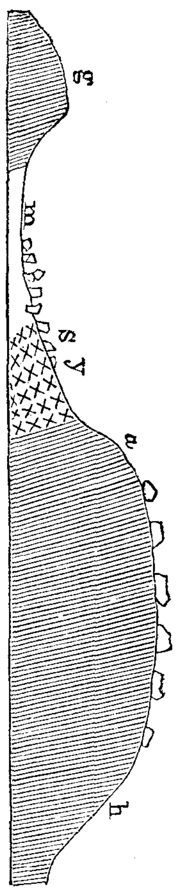


Fig. 11.

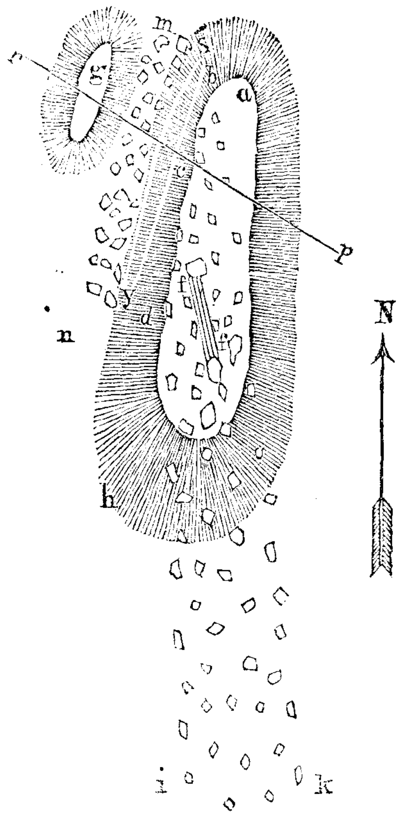


Fig. 10.

m n is a valley with a moderate ascent to the south, with numerous blocks of the syenite, many of them weighing from one to five tons, which have fallen down from the ledge above.

ff, furrows and scratches on the slate with direction north 15° west.

In the direction towards *i k* the stream of stones is prolonged nearly a mile beyond the southern termination of the hill, into a valley which is much lower than any places represented in the figure.

r p is the line of the section seen in figure 11, in which the same things are represented by the same letters.

This syenite is mostly a very coarse highly crystalline compound of black hornblende, and greenish horn-colored feldspar, and although composed of the same materials as greenstone, its coarse crystalline structure indicates its hypogene origin. No

other rock in the State has yet been found, which resembles the coarse variety which is by far the most common.

Several other cases are known to me, which are probably of a similar character, but the rock is not so peculiar and local, where the angles of the fragments have been partially obliterated by the decomposing agency of the atmosphere, so that these cases do not materially differ from the more common phenomena of drift.

Fracture of Slate Hills.

This very remarkable class of phenomena may be regarded, although not with absolute certainty, as the effect of drift agency. So rare are the examples, that it is believed that the cases, which exist in the south-east corner of Vermont, exceed in number all others which are known at the present time.

One of these localities, Bruce's quarry, in the east part of Guilford, has acquired some celebrity from the figures and descriptions of President Hitchcock, and of Dr. C. T. Jackson. The others have been discovered in the progress of this survey.

In these slate hills, the laminae of roofing slate stand nearly perpendicular, but in the upper portion they are fractured and inclined from the lines of fracture. In some of the fractured masses, the laminae retain their former relative position without any intervening spaces. Other portions, however, in the summit of the hill, (two cases of this kind have been observed), have been broken into loose fragments lying horizontally, or nearly so.

At Bruce's quarry, which is on the west side of a hill, the south-western portion of the fractured slate has been removed, so as to afford a transverse vertical section, (fig. 12) at the north end of the quarry, of a part of the fracture, and a longitudinal section from this to the southern extremety of the fracture, (fig. 13.) The crushed portion, so far as uncovered, is about one hundred feet from north to south, and forty feet from east to west. The direction of the uncrushed strata is north 5° east, with a dip of 72° west. At the north end of the crushed portion, the dip is 32° to the east 20° south, and at the south end the fragments lie more loosely and irregularly, with scarcely any dip. The transverse section (fig. 12) represents the most compact portion at the north-west extremity. This section fronts south, and is about five feet by four. So closely united are the layers, that it might be supposed that the mass had been forced over without their slipping upon each other, were it not for the transverse fractures, *a a a*, which reveal the manner in which they moved upon each other, as they changed their inclination, but ***retained their parallelism.*** In the south part of the disturbance, on the other hand, the layers are broken into loose fragments, as represented in the other section, (fig. 13, *a*,) the space being about seventy-five feet from north to south.

Fig. 12.

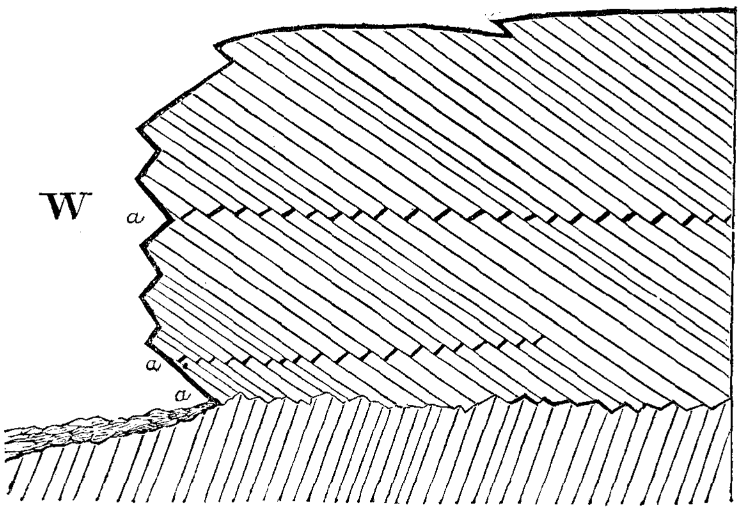
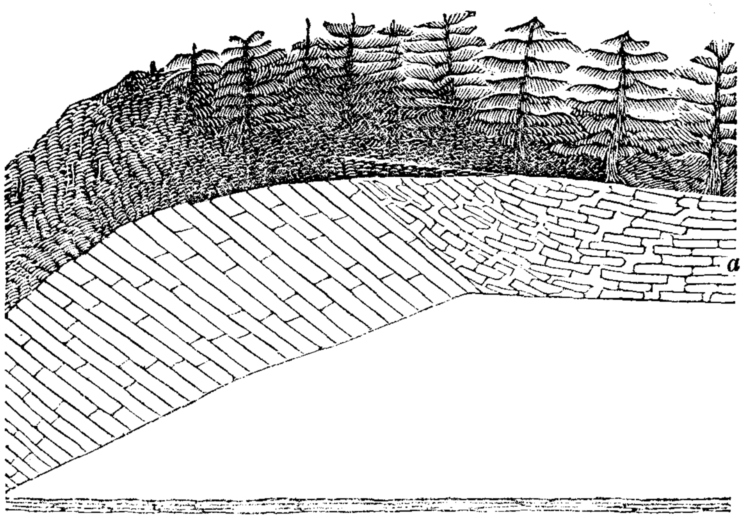


Fig. 13.



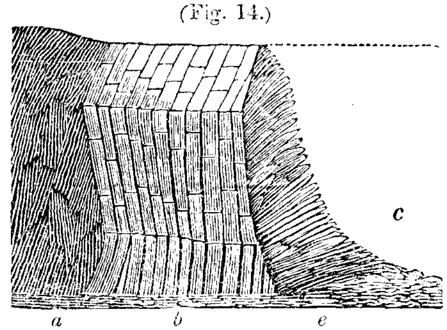
About sixty rods to the south of the spot figured above, a small portion of similarly fractured slate was removed, four years since, in the process of quarrying. Indeed, President Hitchcock

is of the opinion, ("Trans. of Am. Assoc. of Geologists"), that the whole summit of the hill has been fractured, and that much of the fractured masses has been since swept away.

Half a mile north of Bruce's quarry, near the western *base* of the hill, a brook has revealed more of the slate, which has been fractured and forced over in the same direction. The top of the hill here exhibits no fractured masses.

In the north-east part of Guilford, is Willard's quarry, (near the Brattleborough line, three miles from Bruce's quarry), where the top of the hill is quarried, and presents similar phenomena. The top and north-west part of the hill are crushed over, in about the same direction as at Bruce's quarry. The layers are perpendicular, and the direction is north 25° east, both in the fractured and unfractured portions of the ledge. The most conspicuous part of the dislocation has been exposed by quarrying, and is repesented in the accompanying figure, of a vertical surface facing south, about ten feet high. *a* is the west part of the hill, covered with drift; *b*, slate, the lowest part not fractured, the rest fractured; *e*, loose fragments of slate thrown over to the east by frost. The opening *c* has been made by quarrying, in which process a large quantity of fractured slate was removed.

(Fig. 14.)



The strata, not being free to yield to either side, had been crushed into a zigzag arrangement, and are quite loose but parallel. Those, which have been left, by quarrying, unsupported on the east of this mass, have more or less fallen over in a divergent manner, by atmospheric agencies. It was immediately obvious on inspection, that the present position of these divergent strata was owing to a very different agency, from that which fractured the principal mass, and Mr. Willard informed me that they had assumed this position since the working of the quarry, which was opened about thirty five years previous. The upper part of the slate, two rods south-east of the mass figured, is fractured similarly to the upper part of this mass, to which it corresponds in position. Mr. Willard said that when the quarry was opened the slate was found fractured.

Brattleborough. Near the south-east corner of the town, rather more than a mile south of the east village, and near the top of a hill on its north-west side, a ledge of slate is crushed over in a direction varying from the foregoing examples only 2° or 3°.

But the general direction of the laminæ here is north 20° west, the dip being perpendicular. The dislocation extends three feet downwards, having been revealed by quarrying. There is a slight flexure in a few of their layers between their fractured and unfractured portions.

It is proper to acknowledge here my obligations to Mr. C. C. Frost, of B., who pointed out the two preceding examples, as well as the other objects of interest in the vicinity.

DUMMERSTON. In the south-east part of this town is Mr. T. Clark's quarry, which reveals a similar crushing in the top of a hill. The general direction of the laminæ is north 23° east, and dip 78° west. At the north end of the quarry, the layers are crushed over to the width of thirty feet; they are not loosened from each other, but are as closely in contact as in any part of the quarry, especially at the lower part of the fractured mass, where in some of them is a slight flexure. In the fractured portion the layers have been turned round, so as to have a direction of north 75° east, with a dip of 55° north, shewing that the crushing force was exerted from the north 15° west.

In the south end of the quarry five rods from the above mentioned fracture, the slate is fractured into loose fragments, lying nearly horizontally, as at Bruce's quarry. Several other places around the upper edge of the excavation are similarly crushed.

Mr. Clark testified that the ledge presented the same crushed appearance, when the quarry was first opened, 50 years since.

About fifty or sixty rods to the north-east is another hill about thirty feet higher, in the top of which slate was formerly quarried. The fracture covers an extent of several yards, and extends to the depth of one to two feet. The direction of the crushing force appears to have been the same as in other quarries.

The agency of frost is manifest in Mr. Clark's quarry, but it is limited to the joints, which are more open than the planes of lamination. The joints dip about 60° west, and their direction coinciding with that of the quarry, large masses of rock have a tendency to fall into the bottom of the quarry, and are sustained by transverse beams.

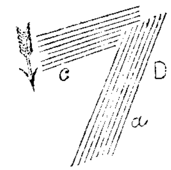
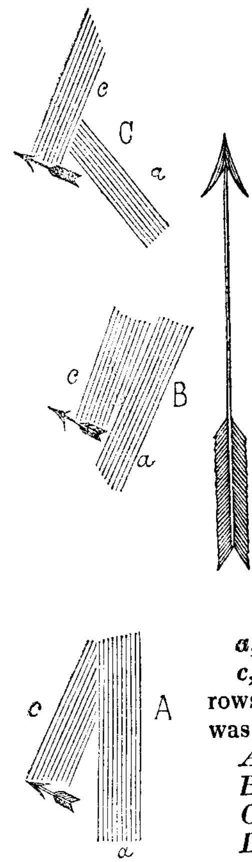


Fig. 15.

Fig. 16.



Omitting the example half a mile north of Bruce's quarry, which is probably continuos with the one at the quarry, the distances between these localities is as follows:

From Bruce's quarry north to Willard's, one mile and a half.

From Willard's quarry north-east to the Brattleborough locality, one mile.

From the Brattleborough locality north-east to Clark's quarry, five miles.

The accompanying figures exhibit the relations of the fractured to the unfractured strata in respesct of direction, and the direction of the crushing force. The two cases in Dummerston, almost exactly coinciding in both particulars, are represented in one figure, (fig. 15), but the crushing force appears to have been in a direction nearly opposite to that of the other cases.

a, general direction of the strata.

c, direction of the crushed strata. The arrows indicate the direction in which the force was exerted.

A, Bruce's quarry.
B, Willard's quarry.
C, Brattleborough locality.
D, Clark's quarry.

The *age* of these fractures, although they are overlaid with drift, does not seem to be directly indicated, and opinions on this point will depend on the theory of the cause. If we should suppose that they are the effect of some force from above, in connection with the flow of water, then they must be referred to the period of the drift agency, since we have no evidence that these slate hills have been under water at any other period since their deposition.

Several theories have been advanced to account for the fracture at Bruce's quarry, the only one of the above examples which has been described heretofore.

In the first report of the geology of New Hampshire, Dr. Jackson describes and figures this example, and accounts for it by supposing an overlapping of a portion of the strata succeeded by a lateral thrust; and his figure represents on the top of the hill such an overlapping mass, whose lateral thrust would necessarially crush over the strata. If the figure be correct, the theory would seem to be well sustained. President Hitchcock, however remarks:

"Soon after noticing this opinion, I revisited the locality, and made a careful examination of it with reference to those views; and I must say that I could not discover the least evidence of any disturbance of the strata beneath the fractured laminœ; nor of any crossing and overlapping of the strata; nor of a lateral thrust; nor of unstratified rocks within several miles of the spot. If the figure accompanying Dr. Jackson's account was intended to represent the quarry (of which I am not quite certain, from his language,) I must observe, that I could not discover, at the quarry, the thick mass of slate represented in his figure as lying in a north-east and south-west direction, and pressing against the fractured laminæ."

Perhaps the nearly horizontal fragments, occupying this part of the hill, (Fig. 13, *a*,) may have been the ground, on which it was supposed that there was such a mass of slate, as is represented to have caused the fracture. This theory perhaps would have had the preference, had it not proved on reëxamination to have been totally at variance with the facts in the case, and accordingly Dr. Jackson has subsequently abandoned both the theory and the figure, and in his final Report has proposed another theory, with an excellent figure which very accurately represents the appearance of this part of the quarry, except that the curved and loose condition of the strata represented at the left of the figure do not exist, but that which is represented in our figure, (fig.12), Dr. Jackson now proposes the agency of water freezing between the laminæ of slate, as the cause of the fracture. The manner in which frost acts in these quarries we have already shewn, and the effects cannot by any means be confounded with these fractures; frost entering deeper in successive years causes the perpendicular layers to diverge, opening upwards. But a large portion of these layers are perfectly parallel, and as contiguous throughout as any unfractured laminæ; nor could the expansion of frost break off the strata, and then throw them down loosely in a horizontal position in the middle of the top of the hill, before the quarries were opened, as in Bruce's and Clark's quarries, but its principal effects would be in the outer portion of the mass. But the case of Willard's quarry is, if possible, more in point; here nature has shewn us, side by side (Fig. 14,) the difference between the agency of frost, and that which caused these fractures; and even without this contrast, the zigzag condition of the fractured yet parallel layers, which were not free to move on either side, incontestibly points to some force acting in this instance almost directly *downwards*. Notwithstanding, therefore, a strong predilection for the simplicity of this theory, we cannot regard it as consistent with the facts. The third theory is that of President Hitchcock:

"The expansion of a vast mass of ice, resting on this spot, or its movement by any other agency, might have produced the fracture. The direction in which the force must have acted here, however, is nearly at right angles to that taken by the drift in that part of the country; so that if the ice were the agent, it must there have made a lateral movement; perhaps in consequence of an enormous mass striking against the hill east of the quarry."

The most obvious objection to this theory is that which President Hitchcock suggests, of the direction in which the force acted in the case of Bruce's quarry. But it now appears that there are three examples, whose extremes are two miles and a quarter distant, in which the force coincided almost exactly in direction, so that it is not easy to avoid the conclusion of a common or at least a similar cause; and as the examples of drift agency everywhere shew that to have been exerted in a direction nearly opposite to this, the difficulty of referring these facts to the force of the drift current is greatly magnified.

But it is difficult to conceive how masses of water could have frozen on the tops of hills so as to crush over the strata in one direction only in one region and in the opposite direction only in another. Moreover, the direction, in one case at least, appears to have been, not that of a force moving on the surface, but coming down upon the top of the hill.

We had intended to propose as a theory the toppling over of floating icebergs, which are well known by unequal melting to change their centre of gravity, and roll over. The effects are indeed precisely what we should expect, if enormous icebergs should, while thus rolling over, strike upon the summits of the hills; the zigzag appearance of the fractured slates in Willard's quarry, and the masses nearest the centre of the hill lying in loose fragments in a nearly horizontal direction would be accounted for. This, however, would not account for the coincidence, for although the two hills in Dummerston, being only sixty rods distant, may have been crushed by the same blow notwithstanding their difference of height, thirty or forty feet, yet it cannot be supposed, that the same stroke of an iceberg fractured hills two miles and a half distant, for a mass of ice of this horizontal extent would not turn over, unless at least as high as wide, a supposition too improbable to be entertained. It has been suggested by Mr. Darwin that some similar cases in Wales may have been the effect of "icebergs lifted up and down by the tides;" or, rather as President Hitchcock has recently suggested to us, huge icebergs rising and falling by the undulations of a heavy sea may have thus struck the hills with a downward force. To this theory there seems to be an apparent objection in the existence of crushed laminæ near the base of the hill; but if we suppose all the overlying parts to have been crushed at the same time and subsequently swept away, the difficulty vanishes.

Age of the Drift.

The entire absence of any deposits of the periods immediately anterior to the drift agency, deprives us of the means of comparison with such deposits, and we cannot here adduce extra-limital illustrations. But the subsequent deposits of the older pleistocene, which we are yet to describe, enable us to place it at the commencement of the grand series of events which they commemorate, and its relations to them are fully and variously exhibited in the facts which belong their history.

In offering a few suggestions respecting the so-called older and later drift, and on the supposed cotemporaneousness of the North American and European Drift, we are compelled, although with much hesitation, to differ somewhat from the opinions heretofore advanced by some eminent geologists.

With a strong preposession in favor of the theory of a double period of drift agency, the latter part of which followed the older pleistocene, we have sought dilligently for the evidences of such later drift overlying the pleistocene sands and clays.

It was indeed sufficiently obvious that the most essential feature of the drift proper,—its universal distribution over all the older deposits in the vast region where it occurs—was wanting to any later masses of gravel and boulders. An examination of the particular cases, which we at first endeavored to refer to a later drift agency, shews that they are not only extremly limited, but referable to different and obvious agencies, unlike those to which the drift is ascribed. In the valleys they are merely the effects of the freshets of existing streams flowing at higher levels, before the obstructions of the drift in their channels had been cut through. They are therefore variously interstratified with the pleistocene deposits. In some cases the waves of the great St. Lawrence and Champlain Bay or Sound of that period spread the drift, from the shores of the then islands, down over the deposits of those waters. In other cases the masses are really drift of the older period surrounded at a little lower level, or nearly covered, with an extremely thin subsequent deposit, and their superposition over the latter is only in appearance. On the other hand precisely similar effects are now resulting from the action of waves and freshets on the ancient drift, in local reärrangements of its materials.

The streams of stones have also been brought forward to prove the existence of a later drift period, but as we have before remarked, until they can be traced over admitted pleistocene deposits, they can be regarded only as the last of the great and long continued agency of the drift proper. Nor can these local coarse deposits be referred to ordinary iceberg agency, since we have abundant evidence, that Vermont was, during the period of their origin, only about four hundred feet below its present elevation.

Finding therefore the grand characteristics of universality, and of a general movement in a given direction, wanting to the so-called 'later drift,' and being able to refer the various supposed examples to well known local agencies or to the older drift, we are constrained to give up the theory of a later drift period. We can here only in this general way mention these facts, having reserved the rather numerous details for future use.

We have before remarked on the satisfactory and lucid generalizations of Sir R. I. Murchison on the drift of Europe, in referring it to a great Scandinavian centre, and we observed that, consequently, it must be independent of the North American drift in respect to the source of the agency, and that the subjacent strata, with existing species of shells, prove the European drift to be more recent than the North American drift, which is overlaid with deposits, which contain not only existing but extinct species. Thus we shall enumerate, among the pleistocene fossils of Vermont, the Nucula Portlandica, the most abundant of the genus in its period, but which the numerous conchologists, who are familiar with the labors of Mighels, Gould, and Couthuoy, on our deep water species, will not hesitate to regard as extinct. Dr. Mighels has described some extinct species of Bulla, which he discovered in the Portland deposit of blue clay. Dr. Jackson also discovered in Maine the Nucula Jacksonii of the same period now extinct. It is obvious, therefore, that we must claim, for the drift of this country, a much greater antiquity, than belongs to that of Europe.

Theories of drift, and submergence of Vermont during the drift period.

Whether this region was entirely submerged during the drift period is a question intimately connected with the theories of drift, one of which, the iceberg theory, necessarily supposes it, and others may be modified to admit or deny it. The facts which we have described relating to the crushed slate hills evidently point to iceberg agency, and consequently to submergence. Yet we cannot claim for this evidence a demonstrative force. The particular discussion of the almost interminable subject of the drift theories, in their relations to the phenomena in this State, we cannot here enter upon. It would be easy, in the language of the subjoined letter of President Hitchcock, " to clip the wings of some hypotheses," which have winged their flight too far into the regions of imagination. Yet the leading features of the more prominent theories, the agency of more powerful waves of translation, moving along the great masses of loose materials over the subjacent solid rocks in oft repeated and long continued pulses, and the icebergs crowding up moraines and shattering slate hills—seem both requisite to acount for the facts.

Older pleistocene.

The deposits refered to this period are, in the order of position,

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 cotemporaneous, 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 each of the above named deposits, we have those which are of marine and those which are of freshwater origin, and although a great part of the former is destitute of organic remains, its connection with the fossiliferous parts, or its elevation, usually enables us to determine whether it is marine. So far as we have ascertained, the marine deposits are limited to the valley of Lake Champlain, and to an elevation not exceeding 300 feet above this Lake. Observations with the barometer in various parts of this valley, mostly in Addison county, with the various elevations determined in rail road and canal surveys so far as we have had access to them, assign this limit of elevation to the pleistocene deposits of the Champlain valley. The greatest height, at which marine shells have been found, does not exceed 200 feet above Lake C., and their greatest known distance from its present shores is but four miles. Yet the continuousness of all

the clays and sands beneath the elevation of 300 feet leads us to refer them to a common origin.

The fossils of the blue clay are Nucula Portlandica (Hk.,) and Lucina flexuosa (Mont.)

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.

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 Lemonfare river, where blue clay is overlaid with muck, which is succeeded by blue clay and then by another deposit of muck. Probably, however, 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.

Some of these blue clays contain a consiberable per centage 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 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.

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, or on blue clay, or on the Champlain and Taconic rocks. We have not yet found it above or beneath the pleistocene sands, but it appears to pass into them laterally. Its fossils are Sanguinolaria fusca, Saxicava rugosa, and Mya arenaria.

The first is found abundantly in various localities on, or within a few miles of the lake shore. 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 occurs at several places, although it was by no means so generally diffused as tha 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. The Saxicava rugosa is more common than the Mya arenaria.

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.

Of the brown clays, in which we have yet found no evidence of a marine origin, there is an extensive tract, probably below a determinate level, in the vicinity of Lake Memphremagog, and there are scattered beds, at various levels in Rutland county and other parts. Probably, however, some of the blue clays have been often mistaken for the brown, since they weather to the same color.

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 this 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 part, a current having perhaps drifted the finer particles of clay to the south. Fossil shells, of the species Sanguinolaria fusca and Saxicava rugosa, are common, but more frequeutly in the lower beds near their junction with the blue clay, where they are exposed by the encroachment of Lake Champlain. A few cases, however, are known 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.

The sands of this period, which are not marine, are very abundantly distributed through the State, mostly in valleys of existing streams, which at a later period have cut away and removed the greater part of these deposits, leaving only their lateral portions in the form of terraces. These deposits lie immediately on the drift, and we have made several sections shewing their position.

We have not yet succeeded in the discovery of fossils in these sands. The lower strata frequently contain aggregated masses of silico-calcareous concretions, which are more or less stained with hydrateof iron.

The local details of these sands are very numerous, and of great

interest, often shewing where existing streams have flowed, at elevations of 150 and 200 feet above their present levels since the drift period; as at Brattleborough, where the Connecticut river flowed on a level higher than the spires of the meeting houses, and at Middlesex, where the same was true of the Winooski; or in Jericho, where they furnish evidence of a lateral communication between the Winooski and the Lamoille.

With these sands occur the overlying or interstratified layers of coarser materials, which have been mistaken for later drift deposits, and on which we have before remarked.

The origin of the older pleistocene deposits may here be very briefly stated.

The general configuration of the surface of the State having been the same for a long time before the drift period as at present, the streams must for the most part have run through the same valleys, and had probably reduced their channels to a level not very different from the present. The drift agency then drifted the enormous amount of loose materials, which had been accumulating since the palaeozoic times, spread them over the surface, and more or less filled the valleys and blocked up their outlets. At the close of the drift period, the surface of the drift must have contained a much larger proportion, than at present, of fine materials, which the rains of the many centuries of the older pleistocene washed down into the valleys, whence the streams carried off more or less of them. The particles of clay being much finer than the sands, the first deposits were mostly of the blue clay in many districts, The long continuance of atmospheric agency converted the blue into brown clay in the drift, and the later deposits are accordingly of brown clay and brown sand: the finer particles of clay were more generally carried to a greater distance in the valley of the Champlain, from their principal sources in the Lamoille and Winooski, than were the heavier particles of sand.

The fineness of the materials, the regular horizontal thin lamination of the clay and stratification of the sands indicate a quiet condition in the depositing waters, for the streams were probably even more quiet than at present in the vicinity of Lake Champlain and Lake Memphremagog, the fall being less by about 300 feet. Occasional freshets interposed between the layers some strata of coarser materials. The hills of drift of the Champlain valley, which now rise more than 300 feet above the lake, were islands, as now appears from the absence on them of pleistocene deposits. The more westerly of these islands were exposed to the waves of the Champlain and Canadian sound, which rolled down the materials of the drift on the sides of these islands in and upon the clay deposits, and these examples of ordinary denudating agency have been mistaken for a later drift, or sometimes occasion the appearance of uncovored drift proper, at a level below that at which the actual section of such cases reveals the clay.

The agency of oceanic currents during this period has excited some attention, and it has even been supposed that the Gulf Stream must have flowed to the north throngh the Champlain valley. On the other hand it would seem difficult to avoid the conclusion that the polar current must have flowed to the south through this valley, for its tendency, even now, in the absence of such an opening, is to the west of south as it enters the Gulf of St. Lawrence, while the Gulf Stream pursues a course to the north-east and east north-east; and since the configuration of the coast of the northern and of the middle states for some distance to the south of the Hudson river was not essentially different from that of the present day, the relative course of these great oceanic currents could not have been materially different. Had the Gulf Stream flowed through this valley, the shells should have been of other species indicating a higher temperature of the water.

The agency of icebergs during this period is also worthy of consideration. Since the depth of the waters over the summit level of the Champlain and Hudson river canal was but about 150 feet, it is obvious that icebergs exceeding a height of 20 feet above the water must have been stranded before reaching those straits, and as the average depth of the waters through the valley of Lake Champlain did not exceed 200 feet, few icebergs could have entered from the valley of the St. Lawrence.

The *climate* of this period has been supposed to have been much colder than at present, in consequence of an error, which very naturally arose respecting the fossil shells, which were said to be of a highly arctic character. We cannot here relate the circumstances which occasioned this error, which is no disparagement to the learned geologists who adopted it. That it is an error we have seen, these shells being the most common bivalves on the coast of New England at the present time. There is indeed no occasion for supposing the climate to have been colder, but if, as we suspect, the peat beds are all referable to a more recent period, there is much reason to believe that it was somewhat warmer. Consequently the theories of the formation of icebergs and glaciers on the mountains of New England during this period fall to the ground. If glaciers could have accumulated any where, it would have been in the valleys of the Lamoille and Winooski, where, however, the perfect preservation of the drift striæ and scratches, in a direction *up* these valleys, prove that in them no glacier agency has been exerted.

Newer Pleistocene.

In the middle and western states, this period is readily distinguished from the historical period by the remains of the mastodon and of other mammalia. But in Vermont, in the absence of these remains, we have no criterion, by which to mark the termination of the last and the commencement of the present period. The greater longevity, which is enjoyed by the species of mollusca, has perpetuated all those which are found in the deposits of the newer pleistocene to the present time. In the absence of any definite character, it may safely be conjectured that the older marl beds and older infusorial deposits belong to this epoch, while it is probable that muck beds were not in a process of accumulation, but characterise the historical period. To the newer pleistocene period also may be referred most of the denudation of the older pleistocene fluviatile deposits, resulting in the terraces which remain on the margins of the valleys.

Terraced Valleys.

Evidences of the fluviatile tendency of this period appear in the terraces, which are more or less common on every river in the state, with perhaps the exception of small sluggish streams, which do not descend from any considerable elevation. They are characterized by a regularly horizontal surface, jutting out from the side of a hill, with an irregular line of margin but uniform slope. In some cases a second terrace makes out in like manner from the first, with a level surface but a variable width, before we descend to the lowest interval in which is the present channel of the river. These ancient river banks are composed of the sand and gravel which characterise the older pleistocene, and for their origin carry us back to that period. They are generally from ten or twenty feet to forty feet high.

The first stage of the process in which the terraces originated, the deposition of the materials, we have before referred to the older pleistocene. The process of denudation must have next followed, when the rivers, cutting down their channels through the drift barriers, lowered them gradually above the barriers. Flowing through the level deposits of sand, they must have formed serpentine channels, as rivers do now in alluvial plains; consequently by increasing the convexity of the bends, and then cutting them off or wearing away their headlands, and shifting their beds, they would be meanwhile removing the greater part of materials thus disturbed. By this process the greater portion of the original plain must have been carried off, and it is not necessary to suppose that the distance between opposite terraces is any in-

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dication of greater magnitude of the river, but only of its shifting its channel.

The process having advanced thus far, we have an interval through which the river flows, and if the channel has entirely cut through the drift, the process is either completed or so much protracted by the difficulty of wearing down the solid rocks, that the progress during even a geological period would be scarcely perceptible, and only one terrace would be formed. But if a terrace has been formed before the complete removal of the obstructions in the channel, the same process must have been repeated within the new and narrower level of interval. We should thus have a second terrace. Repetitions of the process in cases where the obstructions were not entirely removed would occasion a greater number of terraces. In some instances these repetitions have occurred in a valley in which several streams unite and the changes of their channels have left not only many terraces with irregular margins, but detached portions like islands in a horizontal surface in the middle of the valleys. A remarkable case, worthy of protracted and minute investigation, occurs at the village of West Randolph, which is built in the depressions left by this kind of denudation.

This general theory we believe to be applicable, with modifications as local peculiarities may require, to the most if not all of the terraces in this state. In the valley of Lake Champlain, we have a modifying cause in the elevation of the valley subsequent to the older pleistocene period.

These river terraces are obviously different in their origin from some other terraces without the limits of the State, to which we would not apply the same theory ; as the prairie terraces of Missouri territory, especially the Coteau des Prairies, which have no communication with rivers, and which are probably the lines of ancient sea or lake coasts, and which like the present sea and lake coasts have the ground at their bases strewn with blocks of stone (Mather.) Nor should they be confounded with terraces and bluffs near and often parallel to the present sea coast, which were once the lines of coast since elevated by earthquakes, which are found in Chili, which have been described by Dr. Skey in Barbadoes, and which we have seen in Jamaica. Quite different also in their origin, although somewhat similar in form are the parallel roads of Scotland, (see Lyell's Elementary Geology.) We mention these cases for the purpose of contrast, and to restrict the above theory to the terraced valleys of a region of drift.

It has been supposed by some that the sudden bursting of the barriers of ponds, as in the case of the Runaway pond in Glover, has been the cause of these terraces. Not improbably the process may have been more rapid in some cases than in others, but a combination of circumstances, such as a barrier of loose sand protected by a harder cover, is requisite for the sudden bursting of a pond, which would render this the exception rather than the general rule. It would also be only a modification of the theory which we have proposed, which in the introduction of the drift agency accounts for the existence of such barriers. Besides in the only case of the bursting of a pond to which we can refer in this region, we have ascertained that the pond itself was only an excavation in a pleistocene fluviatile deposit, and consequently unlike those which are supposed to have been made by barriers of drift.

Age of the Terraces.

We have already spoken of the period of the commencement of their formation, and have also remarked that this process, if going on at all at the present time, must be far more protracted, in consequence of most of the rivers having come to the solid rock in various parts of their course. If, as is probable, the period of the pleistocene was several times longer than the historical period, it would seem very probable that in most cases the drift obstructions were removed, and that the rivers had come into a condition not essentially different from the present, before the close of that period.

Marl beds.

The distribution of the marl beds is of both scientific and economical interest. The detailed investigations of Mr. Hall shew that the talcose slate region, extending through the middle of the State, is entirely destitute of them, but that they are very common in the region lying east, over the argillaceous and micaceous slates, which are abundantly interstratified with beds of siliceous limestone. In the west part of the State they occur chiefly or wholly in districts where pure or impure limstone occurs. Some idea of the great number of them in the eastern part of the State may be formed, by consulting the Agricultural Report of Mr. Hall further on, although many of the details have been omitted for want of time and room.

These beds occupy basin-shaped depressions, which were once occupied by ponds, or they occur in existing ponds. Many are covered with beds of muck, and some with a heavy growth of timber. They consist of fresh water shells in every stage of decay, of pulverulent carbonate of lime, which has probably resulted from a complete decay of the shells, and of a variable portion of clay.

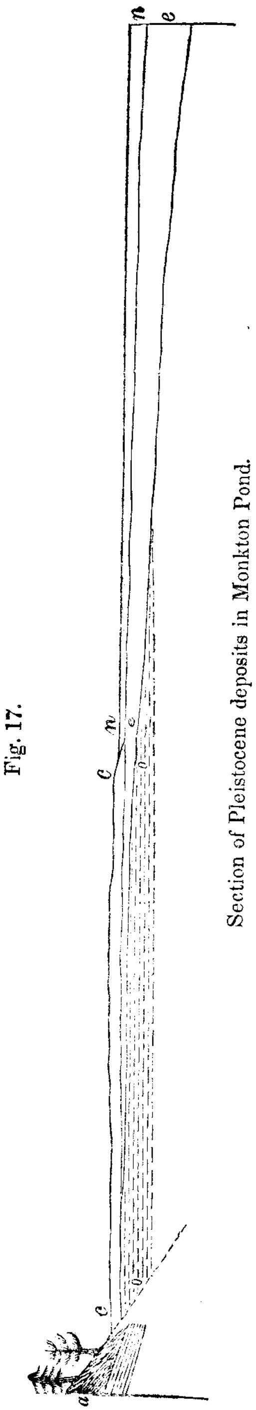


Fig. 17.

Section of Pleistocene deposits in Monkton Pond.

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 represents the several deposits, beginning at the north end of the pond with the hill *a*, and extending about seventy rods into the pond ; *cc*, a muck bed ; *nn*, the pond ; *ee*, shell marl, *oo*, 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.

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.

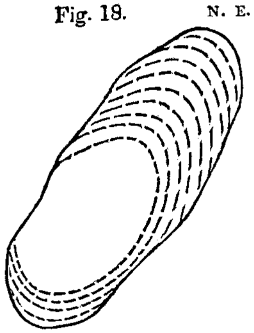
The length of this period is strikingly illustrated in the Monkton marl bed. A long series of years is required to furnish shells sufficient for a single layer, and yet they have accumulated to more than ten feet in depth. 20,000 years is a very moderate estimate for the time required at the present rate of accumulation, and it is more likely to have exceeded this many fold. It is obvious to remark, that, since this is but a part of the time subsequent to the drift agency, the impossibility of identifying that agency with any historical deluge is manifest to the unscientific reader, as it has long been to geologists.

We had intended to have subjoined a list of the species of mollusca, whose shells occur in the marl beds, but having, through the industry of Mr. Hall, a large addition to the specimens, which furnish the data, we have concluded to reserve both the catalogue and the inferences previously made out.

Infusorial deposits.

The deposits of fine siliceous earth, (infusorial silica,) have originated in the flinty shells of animalcules in the same manner as the beds of shell marl have originated in the calcareous shells of mollusca. The same general remarks respecting the age and manner of accumulation of the marl beds are applicable to this. The little attention which we have given to them has been rewarded with the discovery of some interesting examples. Of the most extensive deposit yet known in the State, I subjoin the following report from Mr. Hall :

Fig. 18. N. E.



S. W. Hosmer's pond.

"Hosmer's pond, in the south-west corner of this town contains from 250 to 300 acres, and lies between granite hills. The southwest part is from two to six feet deep. Over the greater part of the bottom, generally above a deposit of muck but sometimes resting on blue clay, is a deposit of infusorial silica. Where the bottom is gravelly, none is seen. The muck varies in thickness below the infusorial deposit. In a few places muck covers it 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, over 14,000 cords!!"

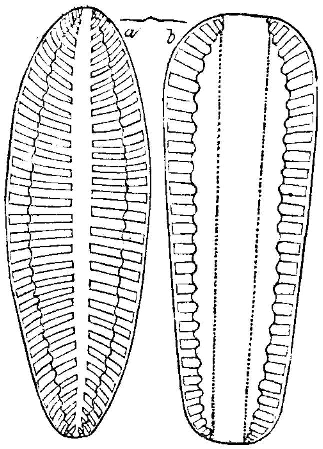
If every cubic inch contains ten billions, the total number, in this deposit, of animalcular shells cannot be less than 20,000,000,000,000,000.

"That part of the pond dotted in the figure was examined, the water being too deep in the central part to admit of being probed by my auger."

I am indebted to the kindness of Professor J. W. Bailey of West Point, for the following remarks on a specimen from this locality.

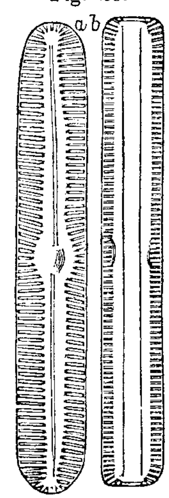
Infusorial forms from Hosmer's Pond, Peacham; magnified 270 diameters.

Fig. 19.



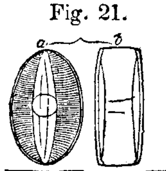
Surirella splendida.

Fig. 20.



Pinnularia viridis.

Fig. 21.



Pinnularia Suecica.

Fig. 22.

Eunotia tetradon.

Fig. 23.

Eunotia decaodon.

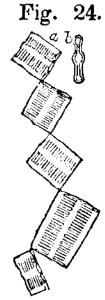
"West Point, New York, Jan. 26, 1846.

'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 this country. It is chiefly remarkable for abounding in very perfect carapaces of that beautiful animalcule Surirella splendida of Ehrenberg. [Fig. 19]. Among the other forms which I recognized are the following:

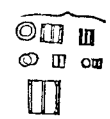
Pinnularia viridis,	Ehr.	[Fig. 20.]
" Suecica,	"	[" 21.]
Eunotia tetraodon,	"	[" 22.]
" decaodon,	"	[" 23.]
Tabellaria trinodis,	"	[" 24.]
Gaillionella varians,	"	[" 25.]
" distans,	"	[" 26.]
Himantidium arcus,	"	[" 27.]
Stauroneis Baileyi,	"	[" 28.]
Gomphonema acuminatum.	"	[" 29.]
Cocconema cymbiforme,	"	[" 30.]
Spongilla lacustris,	"	[" 31.]
" erinaceus.	"	[" 32.]

Fig. 24.



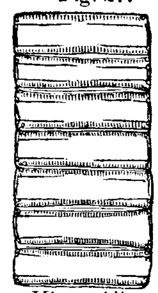
Tabellaria trinodis.

Fig. 25.



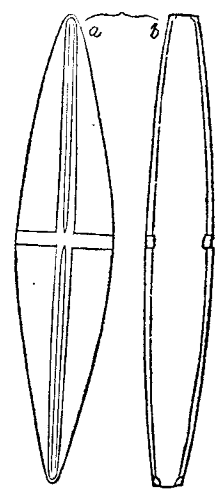
Gaillionella varians.

Fig. 27.



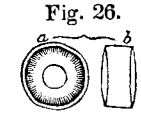
Himantidium arcus.

Fig. 28.



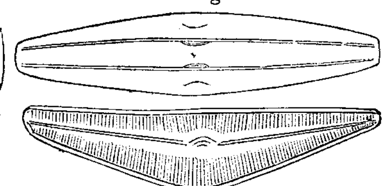
Stauroneis Baileyi.

Fig. 26.



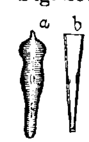
Gaillion ella distans.

Fig. 30.



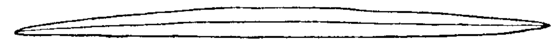
Cocconema cymbiforme.

Fig. 29.



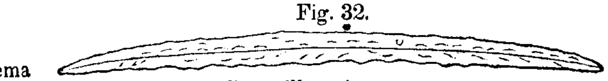
Gomphonema acuminatum.

Fig. 31.



Spongilla lacustris.

Fig. 32.



Spongilla erinaceus.

There are many other species present for which the names cannot be determined until we receive Ehrenburg's forthcoming work, in which all the known species are to be figured and described."

In Maidstone is a less extensive deposit of infusorial silica, on which Professor Bailey has sent me the following remarks.

West Point, February 16th, 1846,

My Dear Sir:—
Your interesting letter with its enclosed 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, (No. 45), 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. 20.]
Pinnularia viridula,	"		
Pinnularia pachyptera?	"	rare.	
Stawronies baileyi,	"	abundant.	[" 28.]
Synedra ulna.			
Himantidium arcus,	"		[" 27.]
Gomphonema acuminatum.		rare in this specimen.	[" 29.]
Eunotia monodon,		Fig. 33.	
&c.			

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.

$2500 \times 2500 = 5{,}250{,}000$ } Five millions, two hundred and fifty thousand in a square inch.

$2500 \times 2500 \times 2500 = 15{,}125{,}000{,}000$ } Fifteen billions, one 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."

HISTORICAL PERIOD.

Since our plan does not permit minute descriptions of the details of the deposits and agencies of this period, we shall merely call attention to a few illustrations. The *deposits* referable to this period are the calcareous, the ferruginous, the manganesian, the organic, and the fluviatile. The *agencies* are those of rains, springs, rivers, and waves.

Calcareous deposits.

Of those which are formed by springs, examples are not rare, In the north east part of Middlebury are several associated springs which deposit a small amount of a very porous tufa. The mineral springs of Williamstown deposit a more solid tufa, 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 bluff, at Lone-Rock Point, Burlington, 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 Mt., Bridport, near the house of Mr. Frost, is a deposit, which had 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 Mallet's Bay, Colchester. At the base of a ledge of siliceous 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. This locality has been supposed to indicate volcanic agency, but it is unnecessary to say that its opposite, aqueous agency, is manifest. In some cases, as in Derby and at Mallet's bay, the tufa contains so much gravel as to approximate to a conglomerate.

Stalactites of small size and irregular form are found in some caverns, as in Highgate cave; and in Chittenden, where have been found the short tooth-like or wedge-shaped stalactites, which form on a sloping roof. But the best specimens have long since been carried off by visitors.

In Pownal, half a mile north of the State line, and near the northeast bank of the Hoosic R., is an interesting example of a calciferous conglomerate and sandstone, in which the process of consolidation is now going on in the mass of drift. A similar but harder calcareous conglomerate of consolidated drift occurs in Westford on land of Dr. Haines.

Ferruginous deposits.

Most of these have been or will be described under the head of *bog ore*, as a part of economical geology. A single example has occurred of a *ferruginous conglomerate* in Warren, where it was found by Mr. Wm. B. Tyler about two miles west of his house, having been revealed by a brook. It is drift cemented by the peroxide and hydrate of iron.

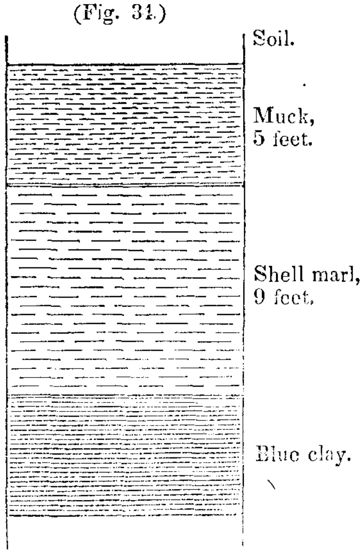
Manganesian deposits.

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 north east part of Benson, there is a bed of this sandstone in a hill side. In Stow, on land of Mr. J. Downer, it occurs with a firmer texture.

Vegetable deposits.

The economical relations of this subject will be treated of elsewhere. These deposits frequently occur in connection with beds of shell marl, which they often overlie.

(Fig. 34.)



The deposit in the north west part of Alburgh, under the Canada line on the farm of Judge Lyman, (see first rep. p. 70,) consists chiefly of small well-decayed plants. Its thickness and geological position are represented in the accompanying section, (fig. 34). It is covered with a growth of timber, consisting of cedar, black ash, tamarack, spruce and pine.

This case is therefore of much interest in reference to the general history of this class of deposits, since the dense growth of timber indicates that the completion of the process of accumulation here is an event historically remote.

Origin of Muck. Many of these deposits have obviously been formed in the bottom of depressed places, which were originally ponds. When ponds are sufficiently shallow, aquatic plants grow from the bottom, and by their decay, commence a deposit of soft mud and vegetable matter. As the process con-

tinues, the waters are more and more excluded, by the filling up of the pond, and other more solid species of plants, and in some cases a dense mat of mosses cover the surface. At length the water is entirely excluded, unless retained in the basin by impermeable strata beneath, in which case a shaking morass may be formed. In other cases, however, the mass becomes sufficiently firm to support a heavy growth of timber. There are some deposits, which have been formed by local accumulations of drifting leaves and stems.

Since the marl and infusorial deposits have been described as belonging in part to the newer pleistocene, we need not here renew the subject.

Fluviatile deposits and agency.

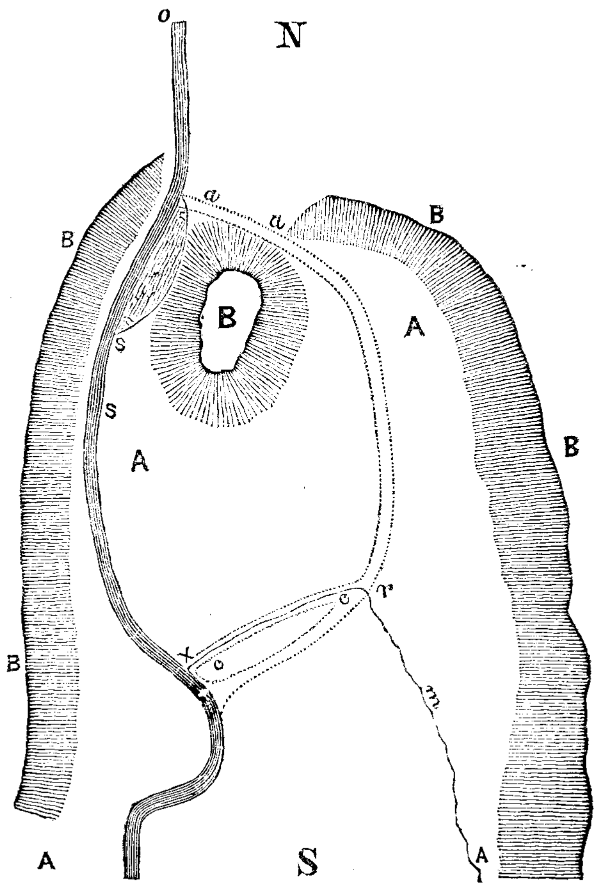
More than two-fifths of the State are watered by the numerous branches of the Connecticut river, which probably carries down about the same proportion of the total amount of solid matter, which is annually removed from the surface. Another portion of this annual waste is carried from Bennington county by several streams into the Hudson. In both cases, the materials are carried out of the limits of the State. But a large portion of the remainder is borne into Lakes Champlain and Memphremagog, in whose quiet depths the fine particles slowly subside. Lake Champlain alone receives the waters from more than two-fifths of the State, and its narrow trough-shaped basin is filling up with a progress, the slowness of which, although not protracted by the loss of any considerable quantity through its small outlet, may be one of our first lessons of the length of time requisite for great changes in the features of the earth's surface.

Occasional floods, although separated by long intervals, are probably some of the most efficient agents in the removal of materials from higher to lower levels, and in filling up the basins of the lakes and numerous ponds. Of the most remarkable flood known in the history of the State, a brief description may be found in the article (New Haven,) in that rich repository of the natural and civil history of the State, 'Thompson's Vermont.' A more detailed account, abounding with thrilling incidents, was also published by one of the principal sufferers. It is therefore unnecessary to give the details at present. On this occasion, a peaceful little stream, whose ordinary current scarcely equalled the flow of blood through the aorta of a whale, was enlarged, until houses were hurled from their foundations and carried down several miles, and areas of many acres were covered with one, two, or three feet of sand and gravel in a few days.

Poultney river affords a very remarkable example of a change of channel, at a locality nearly three miles north west of the village of Fairhaven, and a little south east from the corner of Westhaven. The change occured in 1783, during a freshet, and the neighboring inhabitants say that it was caused by a man running a furrow across the neck (*s s* in the figure) of a peninsula, from motives of ill will to the owners of the property at the falls.

The accompanying figure is referred to in this description, the present channel being represented by continuous and the former by dotted lines.

(Fig. 17.)



B B B B are hills of Taconic slate, more or less covered with drift.

A A A A is an alluvial plain, overflowed before 1783, and overlying a thick deposit of fine blue clay.

a a are the Dry Falls, which are about 150 feet high, with a length of fifteen rods and a direction of north 63° west. The rock here is soft green taconic slate, with a direction of north 5° east and dip of 40° east. The water therefore was precipitated over the edges of the strata, with successive steps, and large holes between them, which are now filled with rain water. On the lower parts of the projecting ridges, where must have been the principal current, are numerous deep furrows, mostly about a foot long, four to five feet wide, and two inches deep, but somewhat deeper in the middle. There are also several pot holes of various sizes, of which one is three feet in diameter; another is two feet in diameter and at least four feet deep, with a small tree growing up from the bottom. A little below the base of the Dry Falls is the junction of the old and new channels, below which the river runs with rapids to the existing falls *o*.

n n is an alluvial deposit, subsequent of course to the formation of the new channel, consisting of slightly argillaceous sand, which was covered, at the time of our visit, April 23, with raindrop impressions, ripple marks, and bird tracks. On the opposite side are low clay banks; but a little farther up the stream we find them much higher, and in the plain A A we find that the river has cut through this plain in alluvium and blue clay to a depth of one hundred and fifty feet, and immense slides, on either side of the tortuous stream, cover an area of several square miles with a scene of violent disturbance. Many of the trees which were growing here before 1783 are yet living, and on the east side are now inclined to the east, by the inclination of the surface of the disturbed masses on which they are growing.

c c was an island in the old channel.

m is a small rivulet, which formerly emptied into the river at *r* and now runs back through the old channel to *x*, having cut the channel on the north side of the island *c c* to a great depth. From this it follows that there was no considerable descent from *x* to the falls, as is now obvious in that part of the old channel which lies between the rivulet and the falls from *r* to *a a*. This is now covered with grass. The old channel was only about ten feet below the banks, the rocks at the falls having been a barrier which prevented a deeper cut.

Quite similar to this was the known and frightful eruption of Long Pond in Glover, described in the American Journal of Science, vol. II. p. 39, old series. To this description we can now only add that the barrier was a fluviatile deposit of the fine pleistocene sand in horizontal layers, and that the pond was a basin excavated in this sand, and as it was upon the height of land in the valley (!), this fact is not easily accounted for.

Action of Waves.

The numerous headlands on the Champlain shore are much exposed to the prevailing north-west and south-west winds, and the cliffs composed of the pleistocene clays are wearing away.

The southern and narrow part of the Lake has its waters deeply discolored by the fine clays derived from these banks. Within five years the road leading south-east from Chimney Point has been washed away in one spot. The numerous morasses along the shore also shew some of the results of this agency.

Rains.

The direct agency of rains, before they form running streams, is chiefly chemical, and in a limestone region the effects are very striking. Rain water, absorbing in its fall a portion of the carbonic acid of the atmosphere, thus acquires the power of dissolving limestone. Accordingly the surfaces of calcareous rocks are much modified by this agency. The effects depend partly upon the position of the surface, and partly upon the structure and composition of the rocks. Sloping surfaces are very commonly furrowed in the direction of the slope, and these furrows are easily distinguished from the drift furrows by their direction being invariably a consequence of the inclination of the surface, and by their irregularity in width and depth, the chemical action being the greatest upon the softer portions of the rock, while the resistless mechanical force of the furrowing agency of the drift was unimpeded by such obstacles. One of the most beautiful examples is at the marble quarry of Slason & Ormsbee in Middlebury; but they may be seen in almost any town on the Stockbridge limestone. By the same agency cracks in the rocks are enlarged into rounded channels, and cavities with some resemblance to pot-holes very closely resemble the effects of the fluviatile agency of some remote period. They are, however, later than the drift, and consequently have been formed since the rivers occupied their present courses. That they are later than the drift is proved by the interesting fact before noticed, that a covering of a few inches, or at least a foot only of clay is necessary to protect the surface from pluvial agency.

Limestone rocks with a jointed structure present the singular appearance of having been cracked by desiccation. The appearance is obviously deceptive, and differs from that of shrinkage cracks, by the regularity of the forms which are thus developed. This results from the chemical action of rain water being more

efficient upon the edges of the seams, which usually cross each other at oblique angles.

The composition of the rock also modifies the result. Through the extensive district of the calciferous sand rock in the north-west, and the still more extensive region of the calcareo-mica slate, in the eastern two-fifths of the State, the surfaces of rock are often seen covered with a more or less crumbling sand, which has been left by the decay of the calcareous portion.

Frost.

The agency of rivers, rains, and waves, is much increased by the effects of frost. Many of the rocks upon the shore of Lake Champlain, especially the Utica slates and Hudson River slates, are very fissile, and are split by the freezing of the water, which penetrates their seams, into innumerable fragments. Examples may be seen on the shores of Grand Isle and in some parts of Addison county. Frost also has a powerful agency in reducing to sand or mud substances which are in any degree porous. By this agency also the decay of land shells is hastened. Within the tropics, the shelter of an overhanging cliff will preserve the shells of many successive generations of terrestrial species, as if in the well guarded drawers of the conchologist, as we once saw much to our satisfaction. But it is in vain to look here for any such accumulations of former generations. Wherever shells are found under the shelter of stones, they are obviously in the process of rapid decay.

TRAPPEAN PERIOD.

The entire absence of any tertiary, secondary, newer or middle palaeozoic formations, leaves a wide blank in the physical history of the State. During these numerous and long periods of time, no deposits were here made and consolidated, which, with their organic contents, should be so many chapters in the book of nature. For the want of such documents, we must recur to the neighboring regions for most of the few general conclusions respecting the history of Vermont during these periods. From the absence of deposits, it may be inferred that the land was above the waters of the ocean, and must, therefore, have been clothed with terrestrial vegetation, and have been the abode of terrestrial animals. Whatever living things, and whatever accumulation of fluviatile deposits there may have been, containing, perhaps, organic remains, during the tertiary periods, were all mingled with the other loose materials that covered the solid rocks, and their distinctive characters were obliterated by the drift agency. The meiocene of Martha's Vineyard is the nearest tertiary deposit, and, with many remains of marine animals, it contains relics of terrestrial vegetation, such as probably flourished over most of New England.

The next oldest formation in the vicinity, is the new red sandstone of Massachusetts and Connecticut. This rock, like most sandstones, contains but few organic remains, the porous character of the original sands having doubtless been, as such are now, unfavorable to the preservation of organic bodies. It abounds, however, with the foot-prints of birds, and of other animals, and since the most interesting locality of these tracks is within ten miles of this State, and this formation approaches within four miles, many of those enormous birds were no doubt familiar with the hills and valleys of Vermont: and if such animals as frequent the margins of tidal estuaries were common, there must have been others more exclusively terrestrial, of which no remains have been preserved. If, too, as is generally supposed, the climate of this period was of tropical warmth in the temperate zone, the vegetation here must have been of tropical luxuriance; and since the climate most favorable to such a growth is also most fatal to its subsequent preservation, we should not for this, as well as for reasons before suggested, expect to find abundant remains of it in the sandstone af Massachusetts.

It is probable that during the red sandstone period, the Connecticut River emptied into a long narrow bay, which reached up from Long Island Sound, nearly to, or quite over the southern line of Vermont, and in which the sandstone deposits accumulated. Consequently no small part of them had their origin in this State, having been carried down by the river. Some of the coarse conglomerates, a few miles south of our southern line, have been found by President Hitchcock, to contain pebbles derived from Vermont rocks, which pebbles would be variously regarded,—by some geologists as indicating violent freshets,—and by others, as the memorials of an ancient period of drift agency. But the most conclusive proof, of the immense amount of materials which have been removed from what was the palaeozoic surface of Vermont, will be found in the history of the trap dykes. President Hitchcock has shewn that the eruptions of trap, whose bold features mark the valley of the Connecticut south of Vermont, took place during the red sandstone period. It is, therefore, not improbable that the dykes of similar greenstone in this State were erupted during the same period.

GREENSTONE DYKES.

It is very remarkable, that, although trap dykes are very common in some districts, not a single example of an overlying mass has been been discovered. The geologist is well aware that such dykes for the most part fill fissures or channels through which eruptions took place. These eruptions, if we may judge from the great number and the distribution of the dykes, must have been extensive, yet the whole body of the erupted materials has disappeared, leaving only so much as was included within the walls of the channels. Had a few masses only been left, we might have been astonished at the vast amount of materials which have been carried off by the various atmospheric, fluviatile and drift agencies of denudation. But a denudation which has not left, in so many cases, a single relic of the erupted trap, must have removed a vastly greater amount. The other rocks, being on the average as perishable as the trap, and having in fact been worn down to the same levels, must have lost an amount proportioned to their superficial extent. In Scotland large districts have been denuded to the depth of three thousand feet, as is shown by remains of the old red sandstone, capping lofty hills. But it is of course impossible, without similar data, to estimate the amount of denudation in Vermont. Since, however, during a great part, if not all the time, which has elapsed since the oldest division of the palaeozoic rocks, a period immensely greater than that portion of it which has succeeded the trappean eruption, the work of denudation has been going on, we may conjecture with much probability that the surface has been removed to the depth of many hundreds, perhaps some thousands of feet. Hence it is not surprising, that there is so much difficulty in determining the manner in which the palaeozoic or primary strata were disturbed from their original horizontal position. Hence, too, we cannot infer with certainty, that there were no comparatively short intervals of submergence and deposition of marine strata, which have been since entirely worn away, but only that the time of emergence and denudation must have been at least much longer. The new red sandstone may have once also extended farther up the valley of the Connecticut into Vermont.

The dykes of greenstone have cut through all the divisions of our stratified rocks, and are therefore proved to be more recent than any of them. In the Champlain rocks, they are most numerous in the vicinity of Burlington, where Mr. Thompson has investigated them with great success. Until recently no dykes were known in the Taconic rocks, but we have discovered several examples. In the middle of the east side of the State, they are also not uncommon in the calcareo-mica slate. Many of them are of much interest, although the rock in immediate proximity does not exhibit any peculiar marks of igneous agency, but the effects of such agency appear to have been extended through large areas.

Of more than twenty dykes, specimens of which we examined last winter, the rock was found in every case to be more or less *calciferous*. We have found these dykes in several cases mistaken for iron ore, or supposed to be an indication of it. Although they contain sufficient to affect the compass, it is far from enough to be of any value. The origin of the dykes is sufficient to show that they do not contain workable ore.

PORPHYRY.

We have been gratified with the unexpected discovery of genuine porphyry, consisting mostly of a base of light reddish brown compact feldspar, and of numerous crystals of the same mineral. A dyke cuts through McNeil's Point, in Charlotte, and is prolonged far to the east. Several cases also occur in Shelburne Point, and have been examined by Mr. Thompson. Since this report has been in press, Mr. T. has shewn us a dyke in Shelburne, there miles west from the lake, composed of a brownish red base with very few light colored crystals, seldom exhibiting more than one crystal in a space of two inches square.

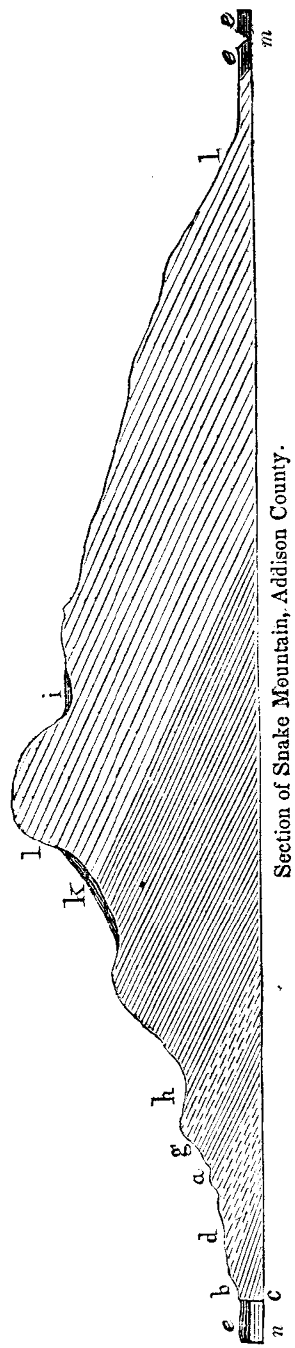
That other important geological events occurred during the long periods which we may call the dark ages of Vermont geology, is proved by the uplifts and plications of the newest members of our palaeozoic rocks. Thus in Snake Mountain, Addison Co., the red sandrock attains an elevation of thirteen hundred and twenty feet above the ocean, by an uplift. A strictly chronological arrangement would require that these events should be described in connection with the period, during which they occurred. But the absence of contemporaneous deposits will render it neccessary to follow, on future occasions, the usual custom, and describe them in connection with the rocks which they have affected. The time is probably distant, when geologists will narrate events, as well as classify deposits, in a strictly chronological order.

PALAEOZOIC ROCKS.

NEW YORK SYSTEM; CHAMPLAIN DIVISION.

These rocks occupy a portion of the valley of Lake Champlain, adjacent to the lake, usually extending from two to eight miles to the east. Near the lake shore, in Addison county, they are repeatedly exhibited, in going north and south, by low, successive uplifts, with a moderate northerly dip. Elsewhere they appear in uplifts, and rarely in plications, which trend a few degrees east of north, with a moderate easterly dip. Want of time and space will permit us to offer only a few miscellaneous notices of localities of special interest.

Fig. 36,



Section of Snake Mountain, Addison County.

The accompanying section of Snake Mountain, whose elevation we have just mentioned, exhibits, in an uplift which has a western mural face, and a strike of north 28° east, all the rocks in Vermont which are known to be fossiliferous.

n. Unknown rock beneath the brown clay four miles north, in a similar situation, covers red sandrock: *n* is undoubtedly one of the middle or upper members of the Champlain rocks. Professor Emmons supposes it to be Trenton limestone.

c. Fracture.

e. Brown clay, extending six miles west to Lake Champlain, where it covers the Trenton and Isle la Motte limestones.

b. Calciferous sandrock; dip 10°.

d. Isle la Motte limestone, dip increasing from 10° to 20°.

a. Trenton limestone; dip 25°.

g. Utica slate; dip 38°.

h. Hudson River shales; mostly covered with drift and debris.

k. Debris, from

l. l. Red sandrock; dip 20°.

i. Cranberry meadow, over liquid peat.

m. Lemonfare River, at the eastern extremity of the section.

The scale is one thousand feet per inch, both horizontal and perpendicular.

This uplift is prolonged, with interruptions, in the direction of the strike into Monkton, where the red rock assumes the lithological character of the granular quartz rock, which has been placed by Professor Emmons at the base of the Taconic rocks, and is, in fact, separated geographically from the northern extremity of that rock by a narrow valley.

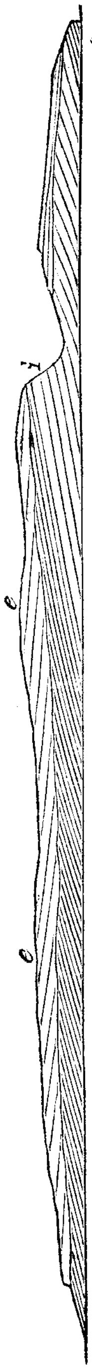


Fig. 37.

Section across Larabee's Point, Shoreham.

The accompanying figure exhibits 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.

e. e. Brown clay.

i. Conformable junction, in Judd's quarry, of the Trenton and Isle la Motte limestones, indicated by change of fossils. Favosites lycopodon being common in the upper strata, and Maclurea 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 described in the first report.

n. Thick bedded limestone, jointed.

o. Thin slaty layers, with slender fucoids abundant.

As eslewhere, the Trenton limestone is rich in organic remains. The best localities are at Larrabee's Point, in the preceding section; and a few rods north of Frost's landing in Bridport; and half a mile north of Chimney Point in Addison, near the house of Mr. Goodale. Fragments which have been partly calcined at lime-kilns furnish beautiful specimens, the shells assuming a pure white color. Some of the species which have been observed are the following: of Polyparia, Favosites lycopodon, and a small ramifying species. Of Crustacea, Isotelus gigas, abundantly in fragments, but rarely well preserved; Trinucleus tesselatus is very common; Calymene senaria and Ceraurus pleurexanthemus. Of shells, Trocholites ammonius, rare; Bellerophon bilobatus; Strophomena sereica in great quantities; S. alternata; Orthis testudinaria abundantly; O. callactis; Delthyris—; Orbicula terminalis; Pterinea undata? Fragments of an Orthocera have been found seven inches in diameter, which probably belong to this formation.

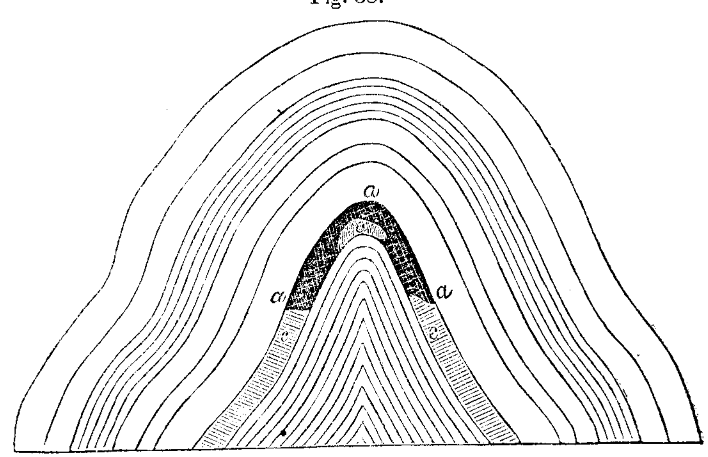
We have used the name, Isle la Motte limestone, to include the several members known as Chazy and Birdseye limestone, &c. since they are most fully exhibited in the Isle La Motte, where

the fossils are abundant, as mentioned in the Report of last year. The finest specimens of Maclurea, which we have obtained in this formation, are from Panton, near the house of Judge Shephard, where they occur an inch or two in relief in consequence of the more rapid weathering of the rock, and being in various degrees of completeness, several specimens exhibit beautifully all the internal and external structure of the shells. They are also so abundant as to be nearly in contact in many specimens.

The reader who is not familiar with geology may need to be reminded that all these fossiliferous rocks are marine deposits, as is abundantly testified by their fossils, which are exclusively marine.

Although the disturbances in the Champlain rocks appear for the most part to have been uplifts on one side of a fracture, we have at least one example of a plication, which is worthy of a passing notice, although we cannot here give the full description and figures which the case will require. The plicated rock is the red sand-rock, constituting a hill, which extends through the extreme south east corner of Charlotte into Monkton, for a mile in length. A partial section of the north end reveals the anticlinal axis or summit of the plication, which is still more perfectly exhibited at the south end in Monkton, where the summit of the bend is exhibited in a very fine natural section facing the south. Although a very compact sandrock, and although some strata exceeding a foot in thickness are very pure quartz, yet their continuity is not interrupted in the least by the extraordinary flexure to which they have been subjected, and which is represented in the accompanying figure.

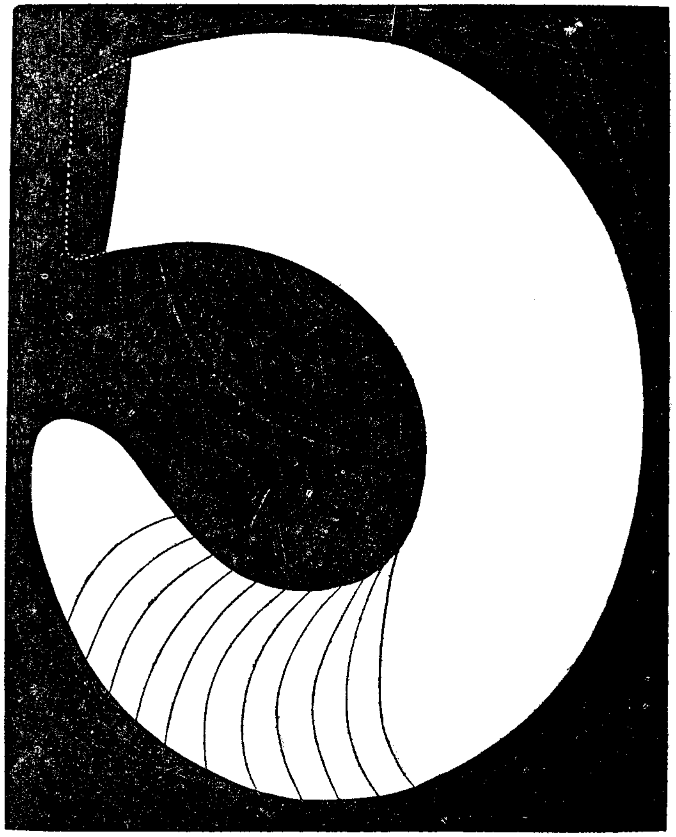
Fig. 38.



"The Oven," Monkton.

The portion represented is thirty feet wide at the base. One of the strata, *c c c*, however, is argillaceous, and has a lamination perpendicular to the plane of deposition, as represented in the figure. The part which is shaded has been disintegrated, leaving a cavern, *a a a*, which is appropriately designated in the vicinity as 'the oven.' The summit of this plication is rather sharply rounded, so that visitors are obliged to walk along the ridge in single file. On the west side, the plication is continued several hundred feet down the hill, in a magnificent series of graceful curves and undulations.

Fig. 39.



Chambered shell, Fisk's quarry, Isle la Motte.

AZOIC ROCKS.

In the last report we enumerated the azoic stratified rocks, under two heads, the Taconic and primary systems. This we did, not intending to adopt, much less to espouse either of the conflicting theories respecting the age of the Taconic rocks, but as a convenient classification. In fact, however, both terms imply theories which are by no means established, and therefore we prefer for the present a term, which simply expresses the fact of the absence of organic remains. Not only is it not to be assumed that the azoic Taconic rocks are more ancient than the palaeozoic, but the same remark may be made of the so-called primary rocks, not a small portion of which may be metamorphic and as recent as the Champlain rocks.

The lapse of the time assigned to the preparation of this part of the report, restricts us to two or three miscellaneous remarks.

A much interrupted granite band extends from Lake Memphremagog in a southerly direction through the State, which, in the adjacent parts of Caledonia and Orange counties is dilated so as to occupy several townships, and has thrown out numerous veins into the surrounding strata. In this granite band is to be found, probably, the great source of the igneous agency, to which the metamorphic character of the azoic rocks is due, rather than in the highest and western ridge of the Green Mountain range, which is twenty to twenty-five miles further west. Accordingly in the northern half of the state, where the mineral constitution of the rock is, with local exceptions, the same, (after receding a few miles west from the granite region,) for thirty to thirty-five miles farther west, viz. talcose slate, we find the summit of a fan-shaped axis separating the more mechanical talcose slate on the west, from the more crystalline talcose slate on the east. This axis is not along the Green Mountain ridge, but six or eight miles to the west; and it is truly surprising how little influence this enormous ridge appears to have on the dip of the strata, which, even in the summit of Jay Peak dip 70° or 80° west, as well as through all that region. These lofty summits, however, have for the most part some lithological peculiarities, the ingredients, talc and quartz, being in coarser grains, so as often to be mistaken for gneiss. West of the axis of perpendicular dip, we have found in the talcose rocks coarse conglomerates, containing boulders of a quartz rock, which are six to eight inches in diameter.

The existence of *Taconic rocks* on the east side of the Green Mountains appears quite evident in Plymouth, where the long narrow valley which extends north and south through the town, is mostly filled with a white limestone, on the west side of which are the brown granular quartz, and ochreous beds of brown iron ore, intimately mixed with more or less of the manganesian ores, and not distinguishable from the numerous beds along the west base of the Green Mountains. It is obvious that we have here facts which have an important bearing on the theory of the plication of the Green Mountains. For, taking, in this part of the range, the gneissoid mica slate or Green Mountain gneiss, as an axis, we have on both sides quartz rock, and next white talciferous limestone and talcose slate interstratified, but most of the latter is outside of the limestone and the ores. Both sides are similar and in the same relative position. Small patches of white limestone are quite common along the east side of the Green Mountain range, in connection with the talcose rocks,—as in Mendon, not far east from the summit; in Hancock, Moretown, Whitingham, &c., besides the extensive one in Plymouth;—so that the inquiry naturally arises, whether these are the relics of a continuous deposit of white limestone, and whether it was not once a continuous part of the great Stockbridge limestone formation, which, with its associated talcose slates, has beeu broken up by plications and denuded through many successive periods. Since the drift period, the decay of the Stockbridge limestone, wherever exposed to atmospheric agencies, has been very great, and with the same rate of decay extending through most of the palaeozoic and the secondary and tertiary periods, there is little danger of over-estimating the amount which has been carried off. If the small beds of white limestone west of the Green Mountains, in the northern part of the State, and in the range of the Stockbridge limestone, should be regarded as belonging to that formation, then our suggestion would be the more probable, since those beds are precisely similar to the others east of the mountains in their position, in talcose slate, and in their lithological characters. It is scarcely necessary to add that these suggestions are made merely as questions that may be entertained, and because we have found throughout the State, that scarcely any, of the many observers of our rocks, appear to have supposed it even possible, that the azoic rocks may not all be primary. But we espouse no theory, Taconic, primary, or metamorphic, in absence of the demonstration of observed facts.

It is proper here to add that considerable labor has been expended in exploration of the geological boundaries of the several varieties of the rocks which were enumerated in the last Report, and that, with the exception of the north east and south west parts, we are prepared to exhibit them by colors on a geological map of the State.

Flexure of argillaceous slate, Guilford; one-fourth of the natural size.

Fig. 40.

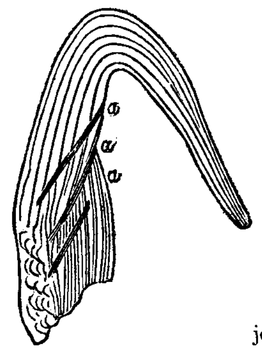


Fig. 41.

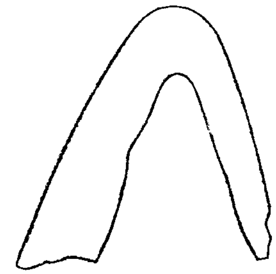
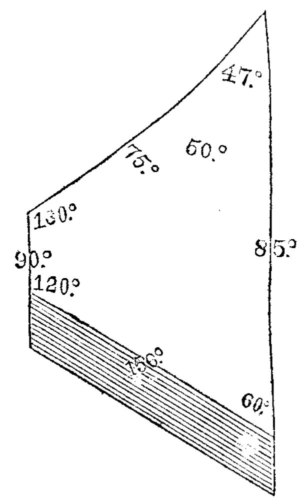


Fig. 40, oblique natural section, made by a joint; *a a a*, small veins of white quartz; Fig. 41, section of the same, not oblique.

Fig. 42.



Jointed specimen of argillaceous slate, Dummerston; one-fourth natural size.

PART V.

ECONOMICAL GEOLOGY AND MINERALOGY.

Most of the economical relations of geology and mineralogy, may be comprehended under the general divisions of Agriculture, Mining, Architecture, and Engineering.

AGRICULTURAL GEOLOGY.

Not only is the fundamental importance of this great art, on which civilized man is mainly dependent for food, more fully appreciated of late years, but the high intellectual rank which should belong to an employment, that is so intimately connected with chemistry, botany, zoology, mineralogy, and geology is also better appreciated. But in Vermont, although many of its citizens are negligent of the true grounds on which agriculture claims a high consideration, this pursuit has never been subject to disrespect; for not only a considerable portion of the men of the learned professions, but the highest officers in the State have been, or are farmers. Happily, therefore, for our State, this art needs not to be elevated in the esteem of the community. These circumstances, the eagerness with which agricultural knowledge is sought, and the enterprise with which it is reduced to practice by many men of superior talents, afford no small encouragement to any attempt to render geology subservient to agriculture.

Having, in the general and preliminary survey of last year, prepared the way for direct effort in this department of the survey, I accordingly directed Mr. Hall, to make a survey of the agricultural geology of the eastern part of the State, in a list of instructions herewith appended to these remarks introductory to his report. It will be seen that this labor has been performed with great diligence and success, and that the almost untouched agricultural resources in the deposits of muck and marl, are truly surprising. Some new countries have a rich virgin soil, but it is of

far greater importance, that there should exist materials, with which knowledge and industry may easily keep up the highest degree of fertility through successive generations. We cannot therefore but regret, that so large a portion of the active young men of the State should abandon their homes for distant and unsettled regions, while, with probably less toil and expense, they may here make for themselves as good farms, as they can find in the far west, with the advantages of a nearer market, a salubrious climate, and the associations and privileges of home.

The value of any, even a small improvement in agriculture, has been forcibly described by a late writer, by reference to the statistics of the business of a community, shewing that an improvement amounting to but one per cent. of increased production, may be absolutely equal to a gain of fifty or one hundred per cent. in other branches of business. A glance at the statistics of Vermont will shew how pertinent is this consideration here. The addition of one per cent. to our agricultural products, would equal the addition of twenty per cent. to all the mineral products of the State.

We had intended to offer some general remarks on the origin of soils, and on the other relations of geology to agriculture, but the report of Mr. Hall renders this unnecessary. It will be seen that Mr. H. has collected numerous statistics, which are not geological, but as they have not interfered with the duties assigned to him, and are, moreover, of much value, no apology can be needed for their insertion.

Instructions to S. R. Hall, assistant geologist, communicated May 1st, 1846.

1. The territory, within which your labors are to be restricted, comprises so much of Vermont as lies east of the principal ridge of the Green Mountains.
2. Sixty specimens of soils are to be collected.
3. Each specimen is to consist of one quart of soil.
4. Each specimen is to be preserved in a stout bag, with its number written indellibly.
5. The specimens should be free from perceptible moisture before they are packed in boxes.
6. The boxes containing the specimens, should be forwarded to this place, [Middlebury], as soon as convenient after they shall have been closed.
7. The materials of a specimen should be a fair sample of the soil of the field selected, rejecting, however, all stones larger than peas. But the proportion of the soil, which consists of stones exceeding this size, as near as can be estimated, should be noted in your journal.

8. The sixty localities of the specimens should be apportioned throughout the above mentioned territory, according to such plan as mature reflection, and your good judgment will mark out; and the principles which govern you should be committed to writing, that they may be published in connection with these instructions.

9. Among the sixty specimens should be some from soils which have not been altered by cultivation,—others from those which have been highly improved,—and a few from those which have been impoverished,—in such number of each character as you may find expedient.

10. Statistics and information will be required respecting the particular soils of which specimens are collected; viz.;

of the crops produced;

of the kind of improvement made, if any, and the manner of cultivation so far as it may affect the character of the soil;

of the depth of the soil;

of the character of the subsoil;

" " " subjacent rocks;

" " " rocks lying to the north a few miles;

of their drainage, and general character of humidity, texture, and other apparent physical properties.

11. If possible, endeavor to arrive at some generalizations on the relation of the soils to the geological character of their vicinity. But if any general propositions are advanced as the result of your investigations, they must be well sustained by well described facts.

12. In immediate connection with the preceding, is the subject of the geographical distribution of the soils, to which the same remarks will apply.

13. You will search for, and examine the natural sources for the improvement of the soil, especially the beds of muck and of marl, and report their extent, depth, and quantity in cubic measure, so far as practicable: also, how much, and in what manner they are used.

14. As a subject of scientific interest, you will, where practicable, make sections of some of the more interesting muck and marl beds, especially when in connection with an existing pond. The remarks made to you in person on the manner of making sections, need not be repeated.

15. Of the marls, which are entirely covered with muck, you will collect as lerge a quantity, as may be convenient, of the shells, which may be easily done by rinsing the marl in a bucket of water. Great care should be taken to collect them in the same proportion of the several species in which they exist in the marl.

16. About one quart of each marl bed may be collected for specimens; and the same from a few of the muck beds.

17. At least once during each month, between the 20th and 25th, yon will write to me for the purpose of keeping me advised of your progress.

18. In devoting a reasonable portion of your time to intercourse with the most intelligent agriculturists, you will endeavor to collect as well as to disseminate information, that you may embody in your report such facts in the various branches of our practical agriculture, as you may deem expedient. In such cases, the name of the agriculturist should be stated; as well as of the owners and cultivators of the soil from which specimens are taken.

19. A report on the agricultural department of the survey must be furnished as early as September 10, ready for the press. This report may include the entire subject of Agricultural Geology, except so far as may be superseded by some general introductory remarks, which I may offer on the importance of the agricultural interest, the relations of the physical sciences to agriculture, and on the origin of soils. (See remarks on page 171).

20. The other objects of the geological survey may, when facts of interest occur, receive a portion of your attention, but not to occasion the neglect of the duties above mentioned.

21. Whatever specimens of rocks and of common minerals may be collected, must be three inches square, not to vary more than half an inch from this typical size, (except for some specific and important reasons, as the exhibition of joints &c.), and from one-half to one inch thick, with one face perfectly free from hammer marks and scratches, and from the effects of weathering. Should you have occasion to pass over any of the spots on which specimens were collected by you last sammer, a few more of the same, with the same number attached, are desired.

22. The directions of last year may be referred to for the number of specimens, manner of packing, &c., your initial H. being added to the number, commencing with number 61.

23. If any trap dykes, not before examined, occur, you will collect specimens, and note the width, direction, and dip of the dyke, and observe whether the rock has polarity.

24. The direction of any drift scratches not before recorded, and kind of rock may be noted. If there be two or more sets, you will look for the evidence of their relative age in the manner of their intersection; but extreme minuteness of observation and particularity of description will be necessary to render your observations available.

25. Whenever claystones are collected, a large numberis desirable on account of the great number of forms. The situation of clay beds may be noted somewhat particularly.

26. Infusorial deposits should be carefully sought for, and specimens collected.

27. Should you have anything to report on the other economical objects of the survey, it is important that such report should be rendered as early as October 15, and that the facts should be described under the same heads and in the same order as in my first report. The facts belonging to the scientific geology, which you may collect, may be communicated subsequently. Your route and the localities whence specimens are taken, should be indicated on a map, of a scale at least twice as large as Mr. Thompson's.

28. Localities of scientific interest are best described by reference to town lines, rivers and objects on the map, as most intelligible to strangers; but those of merely economical interest, by references most intelligible in the vicinity.

29. A geological map of the State has been forwarded to you, and you will note any corrections which you may find neccesary.

30. Should your time of field labor not permit you to go over the whole territory assigned and to finish the plan, you will nevertheless carry out these instructions as fully as practicable, so far as you may go.

Report of Mr. Hall.

To C. B. Adams, State Geologist:

Sir—In accordance with your instructions, I commenced field labor, as assistant geologist, the present season, on the 13th of May; and with only slight interruptions have continued my examinations to the present time. So much of the State, "lying east of the principal range of the Green Mountains" has been visited as the time, allowed me, would permit.

It has been a constant source of regret, that it was necessary for you to assign so large a field, and to limit the time for its examination to three months. The small amount of funds appropriated by the State, for a geological survey, making both unavoidable, I have endeavored to observe the most rigid economy in using the time. But still a part of the field has been unavoidably omitted. Fourteen towns in Windham county, twenty in Windsor, twelve in Orange, fifteen in Washington, eight in Lamoille, twelve in Caledonia, and eighteen in Orleans counties, have, with more or less care, been examined.

I have made it a prominent object to examine the characters of the soil, as well as to collect specimens for analysis; and so far as could be done, have endeavored to visit the best conducted farms, and obtain information with regard to improved methods, and the present history of agriculture, in different sections; also to obtain from intelligent practical farmers, answers to such inquiries as the following:

What modes are adopted for increasing the quantity or improving the quality of manures?

Are there extensive deposits of muck, marl, &c., in the town? To what extent, and how employed?

How many barn cellars in your vicinity, for preserving the urine of cattle as a manure, or preserving the ordinary manure from leaching, bleaching and wasting? What method is adopted for making compost, and to what extent?

About what amount of hay, per acre, do you regard as a fair average for the town?

What is a fair average crop of wheat per acre? of corn? of rye? (if grown,) of oats? of barley? of buckwheat, and of potatoes? Average yield of wool per head from sheep? butter or cheese from cow? &c. When practicable, the estimate of several individuals has been sought, obtained and noted. A copy of these notes is subjoined to this report, with other facts, gathered from individuals, furnishing interesting items in the history of our agriculture.

I regret to say that I have not been able, before rendering this report, to make any examination in the interesting valley of the Connecticut, above Waterford, nor of all the towns bordering on the Passumpsic River.

Two leading considerations have governed me, in making a selection of specimens of soil for analysis; first, to select from each county, a due proportion according to its extent and agricultural importance, and secondly to have each specimen represent as much extent of territory as possible. That I have been able to make selections in every instance as judiciously, as could have been done after more extended are careful examination, is not probable. A catalogue of these specimens will be hereafter submitted. As I was limited to sixty specimens from this field, it was utterly impossible that samples from every variety of soil could be taken, there being very great diversity in the character of the soils examined. This has been found true, often within a territory of limited extent. The intervale on the same meadow, and even on the same farm, not unfrequently, furnishes several varieties differing so materially from each other, as to require considerable diversity in cultivation.

Soil taken from three terraces of the intervale in Charleston, N. H., and analyzed by Dr. Jackson, showed the following diversity of character:

	1st terrace.	2d terrace.	3d terrace.
Water,	2.4	3.4	3.2
Vegetable matter,	4.2	8.1	5.0
Insoluble silicates,	81.0	78.0	79.2
Peroxide of iron,	4.5	4.6	7.3
Alumina,	4.0	4.3	5.1
Salts of lime,	4.0	1.0	0.3

Intervale soil, bordering on a given stream, is not only modified by its degree of elevation, but by the character of the rocks in place and of the drift, over which the water of the river and its tributaries have passed, from which it was deposited. Upland soil often presents still greater diversities, owing to the character and depth of the drift, the qualities of the rock or subsoil over which it lies, the relation of its surface to the dip of strata, and the presence of different proportions of vegetable matter, metallic oxides and earthy salts.

All soils doubtless have been originally formed by the disintegration and decomposition of rocks, through mechanical and chemical agencies. This process is continually carried on, and is well explained in Gray's Elements of Scientific and Practical Agriculture.* The prominent kinds of rocks, which occur east

*"1. The oxygen of the atmosphere combines chemically with the metals and decomposable minerals, and by forming new compounds, causes them to crumble down. Water, also, imparts its oxygen, and produces a similar effect. The surface of rocks, in this way becomes pulverized to a greater or less depth. The principal mineral substances with which the oxygen of the air and of water unite, are iron, manganese and pyrites. When a rock contains iron or manganese, in a lower state of oxidation, these oxides attract more oxygen from the air and water, increase in bulk, and split or cleave into thin layers; thus affording an opportunity for the mechanical agency of water, either by friction or freezing.

2. Pyrites, or the bi-sulphuret of iron, exerts the most powerful agency in the decomposition of rocks, and perhaps the most extensive; as this mineral is widely disseminated through nearly all classes of rocks. It is composed of sulphur and iron. The sulphur attracts oxygen from the air and from water, and forms the well known substance sulphuric acid, [oil of vitriol]. The iron also combines with oxygen from the same source, and forms an oxide of iron. The acid and the oxide now unite, and produce a new compound, the sulphate of iron, or copperas, a substance capable of being dissolved in water. Thus, the rock through which the pyrites is disseminated, is crumbled, thrown, or changed in its properties. But the action does not stop here. The sulphate of iron being dissolved in water, which is constantly penetrating the mass, is brought into contact with feldspar, and both are decomposed; the sulphuric acid in the copperas abandons the iron, and unites with the potash and lime in the feldspar, forming sulphate of potash and of lime, while the oxide of iron is deposited in the form of iron rust. When the pyrites exists in slate rocks, containing much alumina, magnesia and lime, the sulphuric acid combines with these bases, by which nearly the whole rock is gradually converted into soil. Were this the only agent acting upon the rocks, the character of the soil would be accurately known, by examining the rock which underlays it; but this is rarely the case.

3. The mechanical agency of water, aided by cold and heat, and by its currents and waves, not only aids in breaking down the solid masses, but transports the pulverized materials in the form of detritus, and deposits them in lower lands. Thus the substances of different rocks are mingled together. Freezing water exerts an immense power in this respect. The water penetrates every seam and crevice of the rocks, and by its expansive power in the act of freezing, forces the parts asunder, and creates new fissures, which are each year increased in number and width. Nor does this influence cease after the rocks are fully converted into soils; each year the expansive force of water tends to pulverize, and render the earth light and porous. The friction of running water wears off the rocks, and removes that which has become broken down by chemical action. The particles being suspended, and carried down by

of the principal range of the Green Mountains in this State are, talcose, slate, mica slate or Green Mountain gneiss, calcareo-mica slate, gneiss proper, granite, clay slate and horn blende slate.

In Readsborough, Whitingham, Searsborough, Wilmington, Somerset, Dover, Stratton, Wardsborough, Jamaica, Winhall, Londonderry, Landgrove, Weston, Mount Holly and Shrewsbury, towns lying principally in the west part of Windsor and Windham counties, the rock is chiefly Green Mountain gneiss. This kind of rock is composed of quartz, mica and feldspar, chiefly. Pure quartz consist wholly of silica. Mica usually contains of silica about 40 per cent., alumina 12, magnesia 13, potash 7, peroxide of iron 5 to 20, manganese 1 to 2. Feldspar usually con-

the force of the stream and deposited along the banks, and at the mouths of rivers.

4. Decaying plants tend to convert the rock into soils. The vegetable acids are capable of combining with the lime, soda, ammonia, potash, magnesia, oxide of iron and manganese. These bases are thus withdrawn from the rocks, and the latter crumble to pieces, and salts are formed, which are useful in the nourishment of future generations of plants. During decay, large quantities of carbonic acid are formed. This acid is not only direct food for plants, but is capable of combining with the potash in the feldspar of granite rocks, and of facilitating their decomposition. This acid is the most powerful agent in its action upon the alkalies, even decomposing the silicates, and forming soluble salts.

5. Growing plants exert the most powerful agency in decomposing the rocks. Not only do the lichens, mosses and other plants insert their roots into the crevices of the rocks, and by keeping them moist, favor the chemical action of air and water, but the living plant forms with the rock or soil a galvanic battery of immense power; by this means the plant is enabled to obtain from the soil those ingredients which its wants may require. This is proved by the fact, that plants, growing in glass vessels, will decompose the glass, to obtain the potash, of which the glass is in part composed. It is highly probable that a greater amount of decomposition is produced in this way, than by all other causes together. Similar to this influence if not identical with it, is what has been called "catalysis of life." The living plant aids by its presence to decompose the rocks, and to effect rapid changes, which not only convert them into the state of soil, but form the elements into different substances.

The above processes will serve to illustrate the chemical and mechanical agencies, which are constantly at work to crumble down the solid rocks, and bring them into a state fit for the support of the vegetable kingdom. These agents are constantly active. The great effect of stirring the soil, is to facilitate the decomposition of the rocks, and of the vegetable bodies which are always present in the soil. But for this agency, the soils in a few years would become exhausted of all their alkalies, the vegetable matter would not decay, and hence no food in the soil would be provided for the plants. Absolute barrenness must therefore succeed. For without alkalies, or alkaline earths and geine, no plants can grow.

Depth of soil. The influences of the agents above described, has not extended to an average depth of more than 15 feet; although in some places the soil is actually more than a hundred feet in depth. This is but a small portion of the whole mass of the earth, whose mean diameter is 7,911 miles; hence the soil would be less in proportion to the whole earth, than the slightest tarnish of rust on an iron globe 100 feet in diameter compared with its mass. But a small part of this constitutes what is properly denominated the soil.

That part only of the surface, varying from 3 to 20 inches in depth, which has become mingled with vegetable and animal matters, constitutes the true soil, and it is mostly this part which concerns the farmer, and which is presented for our investigation, classification, description, and improvement.

tains silica about 43 per cent., alumina 33, soda 13, potash 7, lime, iron and manganese from 1 to 3 each. As the quartz, feldspar and mica, abound more or less in different parts, the soil that is composed principally of this rock will vary essentially. In most instances that came under my observation, the proportion of feldspar, is very limited, and of course the soil will be essentially composed of of silica, alumina, potash, and vegetable matter,—and be deficient in soda and lime. Lime is however measurably supplied by the drift from the limestone region lying north-west. Both ashes and caustic lime would doubtless essentially improve the fertility of the soil in this region. Talcose slate is found lying east of the Green Mountain gneiss, in the southern part of the State, only two or three miles in width, but north of Plymouth, it is generally from ten to twelve miles wide.

Plymouth, Bridgewater, the easterly part of Barnard and Bethel, and westerly part of Sherburne and Pittsfield, Rochester, Braintree, Granville, Warren, Roxbury, western part of Northfield, Berlin and Waitsfield, easterly part of Fayston and Duxbury, Moretown, Middlesex, Waterbury, Worcester, Stow, Elmore, Morristown, Wolcott, Hydepark, eastern part of Johnson, Sterling and Belvidere, Eden, Lowell, Westfield, Troy and Jay, are embraced in this division, and small parts of a few other towns, bordering on some of these. This rock varies very much in character in different places. It is often filled with veins of quartz on the highlands, by which it is rendered hard. In other places is soft, and furnishes, in some instances, a fine buildingstone.

Talcose slate is composed of silica about 57 per cent., magnesia 27 to 30, oxide of iron 4 to 6, alumina 1 to 2, lime 7 to 10. The quartzose varieties above mentioned contain a much larger portion of silica. Within the limits of this range, are found extensive beds of serpentine and steatite. Serpentine usually consists, according to various analyses given by Dana, of silica 40 to 43 per cent magnesia 40 to 42, water 11 to 12, protoxide iron 1 to 2, lime and alumina a trace. Steatite or soapstone usually contains silica 40 to 43 per cent., magnesia 24 to 26, alumina 0 to 5, oxide of iron 9 to 10, lime 16 to 22. Iron ore in many places, carbonate of lime in one or two, and galena, sulphuret of copper in small veins, in one or two other towns,—one fouud within the limits of this range. Drift covers a very considerable portion of talcose slate rock, and very essentially varies the soil; particularly in the Missisco valley, and that part of the vallies of the Lamoille, Winooski, and White rivers, embraced within this division. The soil is deficient in potash, and lime, and is improved in fertility by caustic lime, ashes, and sulphate of lime.

Bordering on, and lying east of the talcose slate range, is the

calcareo-mica slate region, embracing however, strata of clay slate, gneiss, hornblende slate, and masses of granite.

That part of the State which lies east of a range from Memphremagog lake, to the State House at Montpelier, and thence to Halifax, is wholly embraced in this division, excepting part of the county of Essex, lying north of the head of the fifteen-mile falls. The latter is almost wholly a region of granite and gneiss, and except in the Connecticut valley, mostly an unbroken forest. There is considerable difference perceptible, in a portion of this division, extending from Derby and Holland on the north, to Bethel and Royalton in White River valley, from the other portions, though similar in lithological character. Near the line of the talcose slate, at least north of the valley of White River, is a considerable range of clay slate, and for some distance eastward, this and hornblende slate are interstratified with the calcareo-mica slate, or blue siliceous limestone. These rocks are rapidly decomposing, especially the argillaceous and lime slate, and furnishing new supplies of matter to the soil. There is less drift than in most other parts. The soil is very deep, and more retentive of manure, than that farther east. Randolph, Barre, Hardwick and Derby, furnish examples of this division. The great depth of the soil, the presence of more alumina with the silica doubtless adds to its value. Lime, in the waters of the streams and ponds, has occasioned large deposits of shell marl, furnishing an inexhaustible supply of this substance, for making lime and enriching the soil.

Probably nine-tenths of the marl east of the Green Mountains is found in the towns lying in the division just specified—being from 12 to 15 miles in width, and about 80 in length. The same region is also remarkable for numerous and very deep deposits of muck. Several narrow ranges of granite and gneiss extend from the north line of the State, to a considerable extent, following the direction of the general strata. Such a range first seen at Newport, extends to the north-west part of Albany. Another may be traced from the north-west part of Derby, to the central part of Montpelier, and from to Berlin, and Northfield. Another extends from the east part of Derby to Barre. These ranges are bounded on each side by slate, and vary in width from a few feet to half a mile,—fragments of which in the form of boulders, are extensively scattered over the whole region. The hornblende range, from the high lands in Holland, may be traced in the general direction of the strata to Cabot and Plainfield in the valley of the Winooski.

Granite is composed of quartz, mica, and feldspar or albite. Mica and feldspar usually contain 7 to 15 per cent of potash each, and albite an equal amount of soda. It will be obvious, therefore, that the decomposition of this rock in a limestone region must materially improve the soil, by furnishing these important alkalies.

Hornblende slate, when decomposed, forms a very retentive soil. It is composed of silica 40 to 45 per cent., magnesia 14 to 18, lime 10 to 18, alumina 7 to 12, protoxide of iron, 7 to 18, protoxide of manganese 1 to 2, hydrofluoric acid 1 to 1.5. The hornblende slate is associated with calcareo-mica slate or blue siliceous limestone, and by this union, the soil formed is more porous than it otherwise would be, and is sufficiently dry to produce the best varieties of grass and grain.

The argillaceous and calcareo-mica slates of this region contain generally iron pyrites in greater or less quantities which is rapidly decomposed by the action of the atmosphere, thus facilitating the decomposition of the rock, and furnishing sulphuric acid to the soil. This acid combines with lime, forming gypsum or plaster, and enters into the composition of the most important grains and grasses.

Sulphuric acid "combines with potash, soda, lime, magnesia, &c., and forms sulphates, which exist abundantly in nature, and have often been beneficially and profitably employed as manure. Where the soil contains lime or magnesia, the acid may often be applied directly to the land, in a very dilute state, with advantage to clover and other similar crops. It has in France, near Lyons, been observed to act favorably when applied in this way, while in Germany it has been found better to apply it to the ploughed land, previous to sowing. A few experiments have also been made in this country with partial success."

"Sulphuretted hydrogen is exceedingly noxious to animal and vegetable life, when diffused in any considerable quantity through the air, by which they are surrounded. The luxuriance of vegetation in the neighborhood of sulphurous springs, however, has given reason to believe that water impregnated with this gas, may act in a beneficial manner when it is placed within reach of the roots of plants. It seems also to be ascertained that natural or artificial waters which have a sulphurous taste, give birth to a peculiarly luxuriant vegetation, when they are employed in the irrigation of meadows." (Johnston's Lectures on Agricultural Chemistry.)

Where the rock in place is almost entirely calcareo-mica slate, as in Lyndon, Corinth, Woodstock, &c. and most other parts of the state lying east, and south of the portion just described, there is more danger from drought, and a greater inconvenience is experienced from the leaching of the soil.

The drift soil, excepting where it is clayey, or interval, would be greatly improved, by a heavy dressing of clay, wherever it is practicable. Lime, plaster and ashes will be found highly advantageous, and indeed indispensible, where the liquid manure of the barn is not carefully preserved and applied.

A statement of the preceding facts seemed necessary, in order to a consideration of the natural resources for agricultural improvement. These resources are principally four;

1. Deposits of muck.
2. Deposits of marl.
3. Deposits of clay.
4. Beds of limestone, suitable for burning.

In the division first mentioned, where the rock is mostly Green Mountain gneiss, or a coarse mica slate, small deposits of black muck are found in most towns, and on the streams, deposits of clay. This quality of muck, when united with caustic lime, or wood ashes, or when combined with the urine of cattle, is exceedingly valuable as a fertilizer of the soil. Though the deposits are not usually large, they are considerably numerous, especially in the more elevated portions, and will be adequate to the wants of agriculture there for a long period. On the borders of streams, and for the more sandy or gravelly soil, the deposits of clay will be found of great value. The deposits of muck were much more frequently employed than the latter, but neither of them in a degree commensurate with the claims of the soil, or the true interests of agriculture. A few deposits of brown muck, of limited extent, were noticed at Newfane, Wardsboro', Somerset and Jamaica. Probably others exist on the borders of ponds, or the sites of ancient ponds, of which no information was received.

The talcose slate region abounds in deposits of clay. The soil being much less porous generally, however, than in the former division, clay will be less necessary, except where there is a considerable depth of sandy or gravelly drift. In the higher part of the Missisco valley,—Eden, Hydepark, Morristown, and in most of the towns lying in the Winooski, Dog, Mad and White River vallies, considerable sections were observed where the soil would be greatly improved by a heavy dressing of clay. Deposits of muck, not usually very extensive, but considerably frequent were observed in this region. It seems, however, to have been used as yet, in but very few instances, agriculturists, preferring to employ plaster, lime or ashes. An adequate knowledge of the real worth of the deposits of muck, would lead to a great increase in the use of it, and would proportionably increase the fertility of the soil. Muck of medium quality, would amply repay the expense of transporting several miles. After being thrown up and dried, it is light and easily transported, and in this state, well adapted to absorb and retain ammonia and other salts, existing in urine, &c. Farther examination will doubtless disclose other deposits. No deposits of marl exist in the whole talcose slate region, as far as is known. In the calcareo-mica slate region, especially in that portion of it first described, embracing Memphremagog basin, Clyde, Barton and Black River vallies, and from thence to Royalton, Barnard, and Sharon, in

White River valley, the deposits of muck are both numerous and large. The towns of Derby, Charleston, Albany, Glover, Craftsbury, and Peacham, and probably others, have from two to six millions of cords each ; much of which lying above deposits of marl, will be found as valuable when taken from the beds, as equal quantities of cow dung. Probably few towns, if any, in this section, contain less than from three to five hundred thousand cords of brown muck, of excellent quality. The quantity of marl is also very large. A number of towns, might each furnish enough that is of excellent quality for the manufacture of lime, to supply eastern Vermont for centuries. The deposite at Williamstown, covering an area of some fifteen acres, from six to eighteen feet deep, would furnish probably more than sixty millions of bushels. The enterprising owners of this deposit of marl manufactured some five thousand bushels of lime the last year, which readily sold at the kiln, at twenty five cents per bushel. They are making considerably more the present year. It is found equal to the best lime manufactured in the State. It is the intention of Messrs. Kinsman to construct a perpetual kiln, and thus to diminish greatly, the expense of manufacturing marl into lime.

In Albany, Craftsbury, Hardwick, Peacham, Walden, Royalton, Woodstock, and probably several other towns, the quantity is not much less.

Marl has often been employed as a top-dressing, in the vicinity where it occurs, but without any perceptible benefit. This has induced some to regard it as of no value in agriculture. It should therefore be stated, that, in order to make it possible that marl should be deposited in any place, the soil must contain sufficient carbonate of lime, to have the water of ponds, &c. impregnated with it ; marl being composed of the shells of those animals, that secrete carbonate of lime from water, to form a covering. There is, doubtless, in such cases already as much carbonate of lime necessary, already in the soil.

The marl must be burnt to lime, in order to be of essential service as a direct fertilizer of soils, in the vicinity where found. Marl in the proportion of three or four bushels to a cord, will be very beneficial in compost manures, especially as it contains some other salts, beside carbonate of lime. A specimen analysed by Dr. Jackson, from Brattleborough, was found to contain crenate, apocrenate, and humate of lime.

Most of the marls in Vermont will probably be found upon analysis, to contain phosphate of lime. But as the analysis of them has not been made, farther suggestions, on their nature in forming compost manures, must be deferred until the Final Report.

Of the whole field assigned me for examination, the present year, probably from a twentieth to a twenty fifth part, capable of being brought under the plough or scythe, is meadow or interval, a soil deposited through the agency of streams of water, since the drift-period. That portion, found in the valley of the Connecticut, has generally been regarded as furnishing the best specimens of New England soil. It is doubtful whether better soil can be found, than some portions which might be selected near this stream. The "ox bow" in Guildhall, "cat bow" in Lunenburg, upper interval, "great ox bow," and lower interval, in Newbury, the "bow" in Weathersfield, great meadow in Rockingham, and meadows in Westminster and Putney, furnish such samples.

The meadow or interval lands on the smaller streams furnish very considerable varieties. On Black, Missisco and Barton rivers, the blue clay is almost always found within a few feet, and often within a few inches of the surface, where the meadows are annually flowed. The higher parts have more frequently brown clay, or a mixture of sand and clay. These meadows, when too low to plough, produce a good burden of wild grasses, the quality of which is yearly improving. English grasses thrive well on the higher portions, also oats and corn.

The rivers which flow into the Connecticut, furnish specimens of interval or meadow soil, of almost every variety,—brown clay, fine interval loam, sandy and gravelly loam, and in some cases meadow muck. Brown and blue clay, are of frequent occurrence in the vallies of the Winooski, White and Black rivers, in hills or terraces of moderate elevations ;—the former greatly preponderates. The low lands bordering on the Nulhegan, Wait's, Ompompanoosuck, Quechee, and West rivers, and some of the smaller streams, are more gravelly or sandy, though occasionally brown clay, and alluvial soil of excellent quality occur.

The upland soil varies, as the rock in place varies, and as the character of the drift changes.

Spread over extensive plains, especially in the north easterly portions of Vermont, is a variety of soil, the formation and circumstances of which are difficult of explanation. On the surface is usually from one to three inches in depth of dark soil,—which seems to be a fine loam, mixed with vegetable matter. Lying under this is a stratum of white sandy loam ; from one to twelve inches in depth, as white as the whitest sand of the river deposits. This seems to have been a deposit from water, and is conformable to, and rests upon what appears to have been a previous deposit from water, varying from yellowish to a reddish brown color. It is from six inches to four feet in depth, and usually lies on sand or gravel. I have in a few cases found it resting on rock in place, and in a few others, resting on a sandy brown clay.

When this variety of soil has been ploughed, and manure added, it becomes dark colored, especially where ashes have been added, as well as manure. It is usually productive, and seems peculiarly favorable to the growth of hemlock timber. It is often denominated hemlock soil.

This variety of soil should be carefully analyzed, each part separately, before a full explanation of it can be given.

Little attention has hitherto been given to the subject of reclaiming the natural swamps, and bogs, and converting them into grass lands. Something has been attempted in a few instances, the results of which may be more fully stated in the final report. Col. Prichard, of Bradford, has reformed a bog or swamp, lying in his meadow, and which formerly bore only a wild sour grass, and could not be passed over with a team, by simply ditching, and the application of leached ashes. A heavy crop of foul meadow grass, herd's grass, &c., has been cut on it for several years, and no difficulty experienced in passing over it with cattle. Mr. Stearns, and Mr. Ginne, of Derby, have commenced experiments, the results of which will be stated next year.

It is to be hoped that some enterprising person will purchase and reclaim the great bog in Peacham, consisting of some two or three hundred acres, which would make one of the most productive grass farms in the country, at an expense not much greater than that of clearing an equal quantity of wood-land. Much of it might be ploughed. This bog lies in the valley of Wells River and Winooski River ponds, about equally distant between them. A road will doubtless soon pass through this valley, leading from Newbury to Montpelier by a shorter and more level route than any other.

Many thousand acres of muck meadow, of similar character, in the State, may be easily drained and brought under cultivation, which will then be found among the most productive of our lands. The muck meadow of Judge Lyman, Alburgh, furnishes an example of what hundreds may be made.

Several beds of limestone occur in the southern part of the State, that may be regarded of considerable agricultural importance. That at Plymouth, extending also into Bridgewater, that at Sherburne, one at Weathersfield, one at Somerset, and one at Hancock, may be regarded probably as among the most important. Lime may be manufactured at these places to a much greater extent than at present, and by an improvement in the construction of kilns, at much less expense. There is nothing to prevent lime being afforded at such a price, at any of these places,

as to encourage a much more extensive use of it, as a fertilizer. The limestone of the calcareo-mica slate is burned to a greater or less extent in many towns, and although it contains so large a portion of silex, that it does not swell more than half or three fourths of of its bulk in slaking, it makes a strong plaster, and is highly valuable for agriculture. Mixed with muck in the proportion of three or four bushels to the cord, it will add greatly to the value of it as a dressing for wheat, clover, and potatoes, and indeed for most of the crops grown.

Facilities for irrigation are very numerous, but not very much improved. These will be more valued, as the science of agriculture is better understood. The best specimens of improvements from irrigation will be found described in the notice of Dummerston. Wherever similar facilities occur, similar benefit may be secured.

Much land in Vermont would be greatly improved by ditching. In some situations, both the quantity of iron, and of sulphuric acid, resulting from the decomposition of pyrites, is so great, that nothing of value is now produced. Such places, by being thoroughly ditched, might be reclaimed, and made productive. Many meadows, kept moist by cold springs, produce only a small wild grass, which, if thoroughly ditched, would produce the best varieties of hay. Cedar swamps, regarded in many instances, after the timber is removed, as a nuisance, rather than as beneficial to a farm, may, by adequate ditching, and then applying ashes as a top-dressing, be converted into the most productive and valuable of grass lands.

Though soils differ very much "as regards their immediate origin, their physical properties, their chemical constitution, and their agricultural capabilities," yet, there are very few acres, in the field I have examined, that may not be brought under profitable cultivation. Any soil, containing a sufficient portion of organic matter, may be improved.

"This organic matter consists in part of decayed animal, but chiefly of decayed vegetable substances, sometimes in black or brown fibrous portions, exhibiting still, on a careful examination, something of the original structure of organized substances from which they have been derived,—sometimes forming only a fine brown powder intimately intermixed with the mineral matters of the soil—sometimes scarcely perceptible in either or these forms, and existing only in the state of organic compounds, more or less void of color, and at times entirely soluble in water. In soils which appear to consist only of pure sand, or clay, organic matter, in this latter form, may often be detected in considerable quantity.

"The proportion of organic matter in soils which are naturally productive of any useful crops, varies from one-half per cent. to seventy per cent. of their whole weight. With less than the former proportion they will scarcely support vegetation;—with more than the latter, they require much admixture, before they can be brought into profitable cultivation.

"It is only in mucky and peaty soils that the latter large proportion is ever found. In many of the best soils, the organic matter does not average five per cent., and rarely exceeds ten or twelve. Oats and rye will grow upon land containing only one or one and a half per cent. of vegetable matter; barley, where two or three per cent. are present; but good wheat soils contain in general from four to eight per cent., and if very stiff and clayey, from ten to twelve per cent. may occasionally be detected.

"Though, however, a certain proportion of organic matter is always found in a soil distinguished for its fertility, yet the presence of such substances is not alone sufficient to impart fertility to the land. The earthy part of soil consists principally of these ingredients:—

1. Of silica, siliceous sand, or siliceous gravel—of various degrees of fineness, from that of an impalpable powder as it occurs in clay soils, to the large and more or less rounded sandstones of the gravel beds.

2. Alumina—generally in the form of clay, but occasionally occuring in shaly or slaty masses more or less hard, intermingled with the soil.

3. Lime, or carbonate of lime—fragments more or less large of the various limestones that are met with near the surface in different places. Where cultivation prevails, it often happens, that all the lime the soil contains has been added to it for agricultural purposes—in the form of quick-lime, or of one or another of the numerous varieties of marl, which different districts are known to produce.

"It is rare, that a superficial covering is any where met with on the surface of the earth, which consists solely of any one or these three substances—a soil however is called *sandy* in which the siliceous sand greatly predominates, and *calcareous*, where, as in some of our limestone districts, carbonate of lime is present in considerable quantities. When alumina forms a large proportion of the soil it constitutes a *clay* of greater or less tenacity. The term clay, however, or pure clay, is never used by writers on agriculture, to denote a soil consisting of alumina only, for none such ever occurs in nature.

"Soils in general consist in great part of the three substances just named, in a state of mechanical mixture. This is always the case with the sileceous sand, and with the carbonate of lime—but in the clays the silica and alumina are, for the most part, in a state of chemical combination. Thus, if a portion of stiff clay be kneaded or boiled with repeated portions of water, till its coherence is entirely destroyed, and if the water, with the finer parts which float in it, be then poured into a second vessel, the whole of the soil will be separated into two portions—a fine impalpable powder consisting chiefly of clay, poured off with the water, and a quantity of siliceous or other sand in particles of various sizes, which will remain in the first vessel. This sand was also mechanically mixed with the soil. The fine clay contains still some mechanical admixtures, but consists chiefly of silica and alumina mechanically combined." (Johnston's Lectures.)

Notices of towns, and estimates of agricultural productions, &c.

[In the daily journal, such facts were occasionally recorded, as were supposed to be adapted to convey information of general interest, although not always specially relating to geology.]

Albany. On the farm of Mr. Zuar Rowell, east of great Hosmer's pond, is a very valuable deposit of marl, lying under a deposit of muck—about four feet deep. The marl varies from four to eight feet thick, where examined, and covers from six to ten acres. Both the muck and marl are of excellent quality. The deposits are in what was anciently a natural pond, enlarged by a beaver dam, now entirely filled up. The meadow has been partially drained, and could be effectually at a little expense. Quantity of muck on an acre, twelve to fifteen hundred cords. Marl probably three hundred cords.

A small stream passing through this meadow is made to turn a water-wheel, which works a forcing pump, placed in the bottom of a small cistern supplied with water from a valuable spring. By this pump, water is forced through logs, to the barn of Mr. Rowell, more than twenty-five feet higher than the spring. The expense of this ingenious contrivance is only a few dollais. Besides the water-wheel and aqueduct, the expense is not more than a dollar. On land of Mr. G. W. Powers, in south east part of the town, is a 'beaver meadow,' containing five or six acres of muck four or five feet deep, beneath which is a deposit of marl, resting on gravel and blue clay. This marl is mixed with clay in some places. Half a mile north of this is another deposit of marl fifteen to twenty acres, on land of Mr. Orne. Muck three to five feet deep—and marl eight to ten. This marl is of excellent quality. It is on the borders of a pond, which may easily be drained, so as to procure the marl without difficulty. This pond now covers but a few acres, and will eventually be entirely filled up, by the agents which have already diminished it to a tenth part of its former size. In the north east part of the town, there is a very large 'beaver meadow,' containing, as I was informed, from one to two hundred acres, where the muck is very deep, under which it is supposed there is marl. A large deposit of muck is found on the borders of the creek, passing through the whole easterly part of the town, and also on the borders of several small ponds. Several valuable deposits are found in the river valley, on land of Mr. Church, also on the farm of widow Hovey, and on farm of Mr. ——, near the new meeting house. This latter deposit, is probably a beaver meadow; the muck is from four to six feet deep, where examined. It gives the odor of sulphuretted hydrogen, when penetrated, so as to be exceedingly disagreeable. There are in this bed ten or twelve acres. Several other smaller deposits would probably swell the amount of valuable muck in this town to three or four millions of cords, and it is so well distributed as to be available to almost every farm. Strange as it may seem, only a few hundred loads have yet been removed and applied as manure.

The rock is calcareo-mica slate. A narrow range of granite occurs in the extreme east part of the town, and another in the north west part. Soil, alluvial on the river, drift on the plains, and principally formed from the rock in place, on the hills.

Estimates of produce, &c., by Rev. E. R. Kilby, and Mr. Warren. Hay on best farms, two tons per acre; average for the town, one ton and a half; wheat 20 to 25 bushels per acre; corn 30; oats 35; barley 30 to 40; India wheat 40; rye 20; potatoes 200; average of wool per sheep, 3 lbs.; butter made from a cow, average, 100 to 125 lbs. a year.

ANDOVER. This town lies mostly in the talcose slate region. Green Mountain gneiss occurs on the west, and calcareo-mica slate on the east part. Small deposits of muck in several places. Soil, mostly drift.

Estimate of crops, &c., by Mr. S. L. Marsh, Mr. Andress and Mr. Burton. Hay less than one ton per acre, on an average for the town; wheat 15 bushels per acre; corn 25 to 30; oats 40; rye seldom grown; barley occasionally grown, yields 20 to 40; India wheat, little grown; potatoes 250; wool 3 lbs. per sheep; a cow yields about 100 lbs. butter a year. Considerable attention paid to raising both sheep and cattle.

BARNARD. This town is about equally divided by the line that separates the talcose slate and calcareo-mica slate. Much of the soil is drift; town generally hilly. There is a valuable deposit of marl in East Barnard. Considerable lime has been made here formerly. The pond in which the marl is deposited is now small, and will eventually disappear.

Estimate of crops, by Messrs. L. Chaney and H. Topliff. Hay rather less than one ton per acre; wheat 15 to 18 bushels per acre; corn 20; oats 30; potatoes 200; barley, buckwheat and rye, grown only occasionally; considerable attention given to growing wool; sheep, Merino and Saxony, yield $2\frac{3}{4}$ to 3 lbs. per head.

BARNET. This town, lying on the Connecticut River, is in the calcareo-mica slate region. A considerable range of clay slate is found near the river. A range of granite passes through the west part of the town. The soil, in the Passumpsic and Connecticut River valleys, is alluvial and river deposit, of good quality. In the westerly part, the limestone is rapidly decomposing and uniting with the drift, and makes an excellent soil. The town, although considerably broken, has an excellent soil for grazing. Many valuable cattle, and some horses are sent to market annually, and large quantities of excellent butter. Deposits of muck are numerous, and considerable quantities of marl are found in several places, from which a good quality of lime has been manufactured.

Estimate of crops, &c. by Jacob Ide, Esq. Hay 1 to $1\frac{1}{2}$ tons per acre, (best farms two tons;) wheat 18 to 20 bushels per acre; corn 40; rye, barley and buckwheat, not estimated; oats 40 to 50; potatoes 200; wool 3 lbs. per sheep; butter 150 lbs. per cow a year.

BARRE. This town is wholly in the calcareo-mica slate region. Ranges of granite in easterly part. Considerable part of the

town is drift soil and the lower parts brown clay and loam; some intervale on the river. Marl, I was told, is found in the south west part of the town. Small deposits of muck, frequent. Soil generally good, though very different in different parts of the town.

Estimates by J. Hale, of the Lower Flat, and Dea. J. Barbour, north part of the town. Hay, about one ton per acre; wheat 15 to 18 bushels; corn 30 to 40; oats 30 to 40; rye 15; barley and buckwheat, little grown; potatoes 200; wool $2\frac{1}{2}$ to 3 lbs. per sheep; butter per cow 100 lbs.; cattle and horses raised for market.

BARTON. This town is in the calcareo-mica slate region; rock in central part is hornblende slate, in eastern part granite. Much of the soil is drift of good quality, and a small tract of brown clay and alluvium near the river. Several beds of muck exist, but none very extensive. Little used at present.

Estimate of produce &c., by J. H. Kimball Esq., and Mr. Mansfield. Hay, one ton and a half per acre; wheat 15 bushels; corn 35 to 40; oats 30 to 40; buckwheat 40; barley 30; rye, not much grown; potatoes 200; wool 3 lbs. per sheep; butter, per cow, 125 lbs.

BERLIN. This town lies partly in the talcose slate and partly in the calcareo-mica slate region. Soil, interval and drift principally. Muck, in considerable deposits in the vicinity of the pond.

Estimate of crops, by S. F. Nye, Esq., and Dr. Smith. Hay one ton to ton and a quarter per acre: wheat 15 bushels; corn 35; oats 30; rye, buckwheat and barley, little grown; potatoes 175 to 200; wool per sheep, $2\frac{3}{4}$ to 3 lbs.; butter per cow, 100 lbs. a year.

BETHEL. Rock talcose slate, and calcareo-mica slate. Most of the soil, river deposit, alluvial and drift. Several deposits of brown clay in considerably extensive tracts, which would greatly benefit the gravelly soil, of other parts, if applied. Deposits of muck are found in several places, and considerably used.

Estimate of crops, &c., by Dr. Alfred Paige. Hay one ton per acre; wheat 15 bushels per acre; corn 40 to 50; oats 25; rye 20; buckwheat and barley are but little grown; potatoes 150; wool per sheep, three lbs.; butter per cow, 100 to 200 lbs. a year.

BRADFORD. The rock in this town is clay, talcose slate and calcareo-mica slate in the east and central, and gneiss in the west part. The interval on the river, though not extensive, is very good. The plain is river deposit and drift. The hills are drift, combined with a soil formed by decomposition of the rocks in place. The soil is of medium quality. The gravelly soil would be greatly improved by a heavy dressing of clay. A valuable deposit of muck on the farm of Col. Prichard, of several acres, was examined. By ditching and applying leached ashes, it is made exceedingly valuable grass land,—but is worth much more for manure. Small deposits of muck in several places, but not much used.

Estimate of crops, &c., by J. W. D. Parker, Esq., and Col. Prichard. Hay, one ton to ton and a half per acre; wheat 12 to 20 bushels; corn 30 to 50; oats 35 to 60; rye, buckwheat and barley, seldom grown; potatoes 200 or less; wool per sheep, three lbs.; butter per cow less than 100 lbs. a year.

Brattleborough. This town, in the Connecticut river valley, has the same rocks, and the same soil with those in the vicinity. The soil is various,—alluvial, river deposit and drift. The clay slate range is here of considerable width. The interval is more siliceous than that of Putney and Westminister, though perhaps equally valuable for some crops. The proportion of sandy loam is greater than in the towns lying farther north. This variety, though not naturally strong, is made highly productive by a judicious application of manure. It was gratifying to find much interest awakened in this town on the subject of agricultural improvements. The efforts of F. Holbrook, Esq. have greatly increased the attention paid to the subject of manures, and to better modes of tillage. A few men equally intelligent and enterprising, in each county, would in a short time, essentially advance the agricultural interests of the whole State. Having received the promise of a written communication from him, detailing some of the modes adopted by him, I need not particularize in this place.

Estimate of average crops, &c., on the interval of Brattleborough, by F. P. Sawyer, Esq. Hay, one ton and a half per acre; wheat not cultivated; corn 50 bushels; oats 50; rye 10; barley 15; buckwheat 15 to 20; potatoes 200.

Bridgewater. The soil in this town is mostly drift. Intervals on the river; sandy, rock in place, mostly calcareo-mica slate; subsoil loose gravel. Several small deposits of muck, but not much used. Beds of clay, along the river, occasionally.

Estimate of crops, &c., by Lymand Raymond, Esq. Hay three-fourths of a ton per acre; wheat 15 bushels; corn 25; oats 30; rye, barley and buckwheat, but little grown; potatoes not estimated. Many sheep are kept; wool per head, 3 lbs.; butter per cow, probably less than 100 lbs. a year.

Brookfield. Rock, calcareo-mica slate. Soil, drift and decomposition of rock in place,—deep on the hills, and retentive of manure. A deposit of marl occurs in several ponds, of good quality. Many deposits of muck are found, but not much used.

Estimate of crops, &c., by Col. Edson. Hay less than one per acre; wheat 12 bushels per acre; corn 30; oats 30; rye none; buckwheat 25 to 30; potatoes 175; wool per sheep 3 lbs.; butter per cow, 75 to 100 lbs. a year.

Brownington lies in the calcareo-mica slate region. A range of granite passes through the west part, and hornblende slate through the east part. Soil mostly drift of good quality, subsoil, gravel, river deposits and alluvial near the river. Many deposits of muck occur, some of which are very large and of excellent quality, though not much used.

Estimate of crops, &c., by William Joslyn, Esq. Hay, more than a ton per acre; wheat 20 bushels per acre; corn, but little grown; rye, little grown; barley 25; oats 35 to 40; potatoes 200 or more; wool per sheep, 3 lbs.; butter per cow, not estimated.

Cabot. This town is hilly. Rock, calcareo-mica slate, hornblende slate and granite. Soil, decomposed rock and drift, generally deep, and productive. Subsoil on the river, gravel and occasionally brown clay.

Estimate of crops, &c., by J. McLean, Esq. Hay one ton per acre; wheat 15 bushels; corn 40; oats 40; rye, barley and buckwheat, not much grown; potatoes 200 to 250; wool per sheep, 2¾ to 3 lbs.; butter per cow, 75 to 100 lbs. a year.

Calais. This town lies wholly in the calcareo-mica slate region: a narrow stratum of granite passes through it. The soil of the hills is mostly from the decomposition of the rock in place, and drift on the borders of streams. A deposit of marl, of limited extent, is found near the centre, from which lime to some extent is manufactured. Numerous and valuable deposits of muck in all parts of the town. The soil is generally very fertile.

Estimate of crops, by G. W. Foster and Jonas Hall, Esqrs. Hay best farms 2 tons per acre, average 1¼ tons; wheat 12 to 15 bushels per acre; corn 40; oats 35 to 40; rye 15; potatoes 150 to 200; wool per sheep 2 and 3-4 to 3 lbs.; butter per cow 100 to 125 a year.

Cavendish. Rock, calcareo-mica slate, and granite. Soil, river deposit and drift, occasional beds of brown clay; subsoil near the river is gravel; small deposits of muck are numerous.

Estimate of crops, by Mr. Adams. Hay, less than one ton per acre; wheat, not much grown, except on the hills, 12 to 15 bushels; corn 35; oats 35; rye 18; buckwheat and barley not grown; potatoes 200; wool per sheep, (Merino and Saxony) 2¾ to three lbs; butter per cow not estimated.

Chelsha. Rock, calcareo-mica slate, very siliceous. Small deposits only of muck and those little used. Soil, river deposit and drift near the Branch; on the hills, decomposed rock in place and drift.

Estimate of crops, by Captain Harry Hale. Hay less than a ton; wheat 15 bushels; corn 25; oats 30; buckwheat 30; rye and barley not much grown; potatoes 100 to 250; wool per sheep (Merino) 3 lbs.; butter per cow 100 lbs. a year.

Chester. Rock, calcareo-mica slate and granite. Soil, mostly drift—considerable interval near the river; subsoil on low lands gravel; only a small deposit of muck. Much of the soil in this town would be greatly improved by a heavy dressing of clay, deposits of which occasionally occur;—plaster, ashes and lime would be highly useful.

Estimate of crops, &c. by Horace Onion, Esq. Hay one ton per acre; wheat but little grown; corn 30 bushels; rye 10 to 15; oats 40; potatoes 150; many sheep kept; wool per sheep (Merino and Saxony) 3 lbs; butter per cow not estimated.

Corinth. Rock, calcareo-mica slate and gneiss. The rock is rapidly decomposing, and unites with drift to form the soil. Deposits of muck numerous and some large;—valuable deposit of marl on land of N. Lovewell, Esq.—it is four to six feet deep, and lies upon blue clay and clayey sand. Lime would be greatly beneficial to the soil, and it is hoped will be manufactured from this bed of marl, for the benefit of agriculture.

Estimate of crops, by A. C. Tenney, and T. Cook, Esqrs. Hay hardly a ton per acre; wheat 8 to 10 bushels; corn 30 to 35; oats 25 to 30; buckwheat rye and barley but little grown; potatoes 200; wool per sheep 3 lbs.; butter per cow 75 to 100 lbs. a year.

Coventry. Rock, clay slate, calcareo-mica slate and gneiss. Much of the soil in this town is clayey drift; on the borders of the lake and on the rivers, river deposit and gravelly drift. Many thousand acres of low interval near South Bay, &c. and bordering on the lake in this town, Newport, Salem and Derby, have become useless, in consequence of a rise in the waters of the lake, occasioned by a dam near the outlet in Canada. The removal of that nuisance is an object of considerable importance, and some time was devoted by me to those preliminary steps which would secure it;—it is hoped it will be accomplished. The soil of this town is very productive; some large deposits of muck are found and numerous smaller beds.

Estimate of crops, &c. by Deacon Frost. Hay one ton and a half, best farms two tons per acre; wheat 15 to 20 bushels; corn 40; oats 40 to 45; barley 40; buckwheat 30 to 40; rye seldom grown; potatoes 250 to 300; wool per sheep 3 lbs.; butter per cow 125 to 180 lbs. a year.

Craftsbury. The rock in the eastern and central parts of this town is calcareo-mica slate, clay slate and granite;—in the

west part talcose slate. Soil near the river low interval and drift; in other parts, mostly formed by decomposition of the rocks. Deposits of excellent marl in great Hosmer, little Hosmer and Duck ponds, and on the borders of these, will furnish an ample supply of lime for the county, for centuries. In the 'natural garden' is an immense deposit of muck: its depth is probably twenty feet or more, and the area probably a square mile; this has doubtless resulted from the partial filling up of great Elligo pond, which obviously once extended nearly to the site of the south village. If the depth is as great as above stated, there are over 4,000,000 cords in this single deposit; large deposits of muck in the vicinity of little Hosmer pond, and in other places in this town, will doubtless furnish as much more.

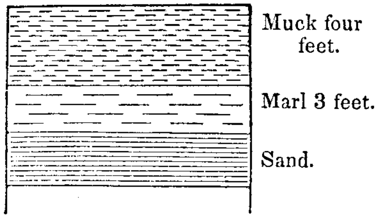
Estimate of crops, &c. by Hon. S. C. Crafts, J. A. Paddock, Esq. Col. Wm. Paddock, S. Root, Esq. and others. Hay one ton and a fourth, to a ton and a half per acre; wheat 12 to 15 bushels; corn 40; oats 40 to 50; rye not generally grown, 15 to 20; barley 30 to 40; buckwheat 50; potatoes 250 to 300; wool per sheep 3 to 3¼ lbs.; butter per cow 125 to 175 lbs. a year.

Danville. Rocks in place, calcareo-mica slate, hornblende slate and granite. This is among the best grazing towns in the State, and though considerably elevated, has, generally, a warm quick soil. Tracts of river deposit are found from five to seven hundred feet above the waters of the Passumpsic. The soil is usually a very deep loam, with occasional pebbles; in some places coarse gravel is seen. The soil in North Danville is of the finest quality: it seems to be a loam composed of the hornblende and granite rocks from the towns north of it, combined with the decomposed blue siliceous limestone in place. Many excellent horses and cattle are raised in this town for market. Marl is found in several ponds; in Keyzer's pond the quantity is large: lime has been manufactured from a deposit in the east part of the town. Muck is found in quantities abundantly adequate to the wants of agriculture, and is used to a considerable extent.

Estimate of crops, &c. by Hon. S. Sias and T. Howard, Esq. Hay 1½ tons per acre, best farms 2 to 2½; wheat 20 bushels; corn 30; barley 25; oats 30; buckwheat 30; potatoes 200; wool 3 lbs. per sheep; butter per cow 100 to 120 lbs. a year; best dairies 150 lbs.

Derby. Rock in place, calcareo-mica slate, and granite. Soil, mostly fine drift; on the borders of the lake, gravelly drift, alluvium, and brown clay. This town has been regarded as inferior to no one for agriculture; deposits of muck are immense and well distributed, and this is beginning to be used with great advantage, being found "fully equal in fertilizing properties to other manure.

Fig. 43.



Estimate of crops, &c. by Charles Adams, Esq. Hay one ton and a fourth per acre; wheat 14 bushels; corn 30; oats 35; rye little grown; buckwheat 35; barley 28; potatoes 200; wool per sheep 3 lbs; butter per cow 120 lbs. a year.

Dummerston. Rock, calcareo-mica slate, and clay slate and granite; the clay slate furnishes good quarries that have been wrought for many years. Soil on the Connecticut and West rivers, alluvial and river deposit, and in most other parts drift. Severable valuable beds of clay, and numerous small deposits of muck occur. Mr. Clark Rice, in the south-west part has from ten to fifteen acres of rich muck, which he has drained, and then constructed a dam so as to flow it at pleasure; the water is then employed for irrigating other parts of the farm, lying lower, and with the greatest benefit, increasing the hay a ton per acre, on some fields. His average crop of hay he estimates at a ton and a half; corn 40 bushels per acre; oats 40 to 50. The soil of his farm is naturally less productive than much of the land in the town, but by a free use of muck and by irrigation, it compares favorably with the best in the county.

Estimate of crops, &c. by Deacon Haven. Hay, one ton to $1\frac{1}{4}$ ton per acre; wheat little grown; corn 40 bushels; oats 35 to 40; rye 10; barley and buckwheat very little grown; wool per sheep $2\frac{1}{2}$ to 3 lbs.; butter per cow not estimated.

Eden lies wholly in the talcose region, is very hilly, and has a gravelly soil. The porousness of the gravel in this town, part of Lowell and Hydepark is peculiar. There is but little muck in those parts of the town brought under cultivation.

Estimate of crops, &c. by Dr. Wm. C. Atwell. Hay less than one ton per acre; wheat 8 to 10 bushels, but little grown; corn 25, little planted; oats 30; buckwheat 30 to 40; rye and barley but little grown; potatoes 200 to 250; wool per sheep 3 lbs.; butter per cow 75 to 100 a year.

Elmore is a mountainous town, and hilly. Rock, talcose slate; soil, decomposed rock in place, and drift; limited quantity of muck.

Estimate of crops, by G. W. Bailey, Esq. Hay, one ton to one and a fourth per acre; wheat 15 bushels; corn 30, little planted; oats 40; rye and barley not much grown; potatoes 200 to 225; wool per sheep 3 to $3\frac{1}{2}$ lbs.; butter per cow, 150

lbs. per year. Mr. B. keeps 30 cows; other large dairies are kept.

Glover. Rock in place, calcareo-mica slate, hornblende, slate and granite; soil, mixture of drift, and decomposed rocks, usually deep, and very productive in wheat. A considerable portion of the bed of "Dry Pond" is in this town. Much of the low land along Barton River was covered with gravel and rubbish, when the pond was drained.

In the bed of Dry Pond, is an immense deposit of a porous substance, formerly in the waters of the pond, which trembles and shakes as it is passed over, and into which a stick may be forced fifteen to twenty feet. It is an excellent manure, and is used in the vicinity. There are eight to ten thousand cords. In the bed of Mud Pond, which was principally drained, the outlet being deepened by the waters of the other,—there is a large deposit of marl. It is made into lime by Mr. Clark, the owner, to supply the town.

Estimate of crops by Mr. Clark, Mr. Dwinell, and Mr. D. Gray. Hay, one ton, best farms ton and half per acre; wheat 20 bushels per acre; corn 25 to 35; oats 34 to 40; rye, barley and buckwheat not much grown; potatoes 200; wool per sheep 3 lbs.; butter per cow 100 lbs. per year.

Greensborough. Rock, calcareo-mica slate, hornblende slate and granite; soil, decomposed rocks in place, and drift. Very productive in grass. Deposite of marl on farm of Mr. Field, of good quality, but not very extensive. Muck abundant, in most parts of the town.

Estimate of crops, &c. by Mr. Stimson, Mr. Ellsworth and Mr. Blake. Hay, one ton to one and a half per acre; wheat 12 to 15 bushels per acre; corn 30, not much planted; rye, little grown; barley and buckwheat not estimated; oats 30 to 35; potatoes 200 to 250; wool per sheep 3 lbs.; butter per cow 125 to 200 lbs. a year. Last year 225 lbs. per cow were sold from some of the dairies, besides supplying the table.

Hancock. This town is situated among the Green Mountains. Rock, talcose slate. Soil, drift; muck in small deposits only.

Estimate of crops &c. by Col. John Hackett. Hay, one ton per acre; wheat 15 bushels; corn 35; buckwheat 30; rye and barley little grown; oats 45; potatoes 200; wool per sheep 3 lbs.; butter per cow 100 lbs. per year.

Hardwick. Rock, chiefly calcareo-mica slate. Soil, drift and decomposed rock, deep and rich, not surpassed by any in the vicinity. A very valuable deposit of marl occurs on the farm of Rev. J. Underwood, and another on farm of Mr. W. Bailey, will supply materials for lime, for the vicinity for ages.

Deposits of very rich muck lie over the marl, and in many other places in the town. Many cattle of fine quality are reared for market.

Estimate of crops &c. by Col. Warner. Half the farms, 2 tons of hay per acre, average one ton and a half; wheat 20 bushels per acre, or more; corn 50; oats 50; rye but little grown; barley 25 to 30; buckwheat 25 to 40; potatoes 300 to 325 bushels per acre; wool per sheep 3 lbs.; butter per cow 175 to 200 lbs. per year.

HARTFORD. The rock is calcareo-mica slate, and clay slate. Soil, river deposit, alluvium and drift, generally of good quality. Considerable tracts of brown clay, which may be very advantageously used to improve the sandy soil in the vicinity of the rivers. Small deposits of muck, but not numerous. Agriculture is here rapidly improving.

Estimate of crops by L. Hazen, Esq. Hay, best farms ton and a half per acre, average, one ton; wheat 15 bushels per acre; corn 40; oats 40; rye 15; barley and buckwheat seldom grown; potatoes 200; wool per sheep 2¾ lbs. (Merino and Saxony); butter per cow 100 lbs. per year.

HOLLAND. There is a beaver meadow in the west part of Holland, on the road from Morgan to Stanstead. It contains about 5 to 7 acres, and has been partially drained. The muck is from 2 to 3 feet deep, below which is a deposit of marl of equal depth, as stated by the owner, (i. e. when the muck is two feet, the marl below it is two feet, and when the muck is three feet, the marl is three feet). Considerable lime has been made here. It is burnt with wood in a kiln, (a layer of wood, then a layer of marl, &c.) The lime is of medium quality and sells at twenty five cents per bushel. The marl rests on blue clay and a clayey gravel.

HYDEPARK. This town is entirely in the talcose slate region. Soil, ancient river deposit, in many places covered with loose gravel. Some tracts of alluvium and brown clay. Several deposits of muck, which are used to some extent.

Estimate of crops &c. by Mr. Matthews, Hon. N. P. Sawyer, and Joshua Sawyer, Esq. Hay, best farms ton and a half to 2 tons per acre, average ton per acre; wheat 16 to 20 bushels; corn 30 to 40; barley not much grown; buckwheat 25 to 30; rye 15; potatoes 200; wool per sheep 3 lbs.; butter per cow 75 to 100 lbs. per year.

JAMAICA. Rock, mostly Green Mountain gneiss and granite. Soil, on the river, drift and alluvium. Numerous small deposits of muck.

Estimate of crops &c. by N. Wyman, Esq. Hay, less than a ton per acre; wheat on the hills 15 bushels per acre; corn on the river 50; rye 10 or 12; oats 40 to 50; barley and buckwheat not grown; potatoes 150 to 200; wool per sheep 3 lbs.; butter per cow, not estimated.

KIRBY. See St. Johnsbury.

LONDONDERRY. Rock, Green Mountain gneiss. Soil, of medium quality, mostly drift, some alluvial tracts near streams. Small deposits of muck are considerably frequent.

Estimate of crops by J. Stewart, Esq. Hay, rather less than a ton per acre; wheat 12 to 15 bushels; corn 30; oats 30 to 40; barley and buckwheat not grown; potatoes 200 bushels per acre; wool per sheep 3 lbs.; butter per cow not estimated.

LOWELL. This town lies wholly in the talcose slate region, and is, except the valley of the Missisco, mountainous. Soil, in this valley river deposit, drift and alluvium. It is of good quality, and when well cultivated is very productive. Small deposits of muck in several places.

Estimate of crops &c. by T. Wolsey, Esq. Hay, one ton per acre; wheat 20 bushels; corn 35 to 40; oats 40; rye 15; buckwheat 25; barley not grown frequently; potatoes 200; wool per sheep 3¼ lbs.; butter per cow 100 lbs. per year. The farm of Mr. W. S. Flint, in this town is a specimen of what others might become by judicious husbandry. Mr. F. gives considerable attention to growing wheat. His average crop is 30 bushels per acre, on gravelly loam. He applies 20 loads of leached ashes, when the grass land is ploughed, and sows with wheat. The following year he uses 20 loads of barn manure per acre, and plants potatoes. The third year sows wheat and grass seed, and applies 100 lbs. plaster per acre. His crop of potatoes averages 350 bushels per acre, and hay 2 to 3 tons. He has thirty acres of potatoes the present year.

LUDLOW. Rock, in this town, talcose slate and Green Mountain gneiss. Soil on the river, drift and river deposit, and narrow tracts of alluvium. On land of J. Wellington, and Jesse and Ira Bailey, is a large deposit of muck, said to be of good quality.

Estimate of crops, &c., by M. Spoffard, Esq., and Dea. Davison. Hay, less than one ton per acre; wheat 12 to 15 bushels; corn 25; oats 40; rye, buckwheat and barley, seldom grown; potatoes 200; wool per sheep, 3 lbs.; butter per cow, 100 to 125 lbs. a year.

MARSHFIELD. Rock, calcareo-mica slate, and granite. This town is hilly; soil, drift and decomposed rock in place, generally strong and productive. One large deposit of muck near Mr. Dwinells', in the south-west part; another containing 60 acres in the east part; and numerous smaller deposits, are found in other places in the town. It has been but little used.

Estimate of crops, &c., by J. L. Carpenter. Hay one ton per acre; wheat 15 bushels; corn 25; oats 30; rye and barley but little grown; potatoes 250; wool per sheep, 3 lbs.; butter per cow 100 lbs. a year.

MIDDLESEX. This town lies wholly in the talcose slate region. Soil, drift, river deposit and alluvium; generally of medium quality. Very little muck exists.

Estimate of crops, &c., by Holden Putnam, Esq. Hay, one ton and a quarter per acre; best farms, $1\frac{1}{2}$ tons; wheat 13 or 14 bushels; corn 45; oats 50; rye, barley and buckwheat, little grown; potatoes 200; wool 3 lbs. per sheep.

MONTPELIER. The rock in the easterly part of this town is calcareo-mica slate, and granite, and the west part talcose slate. Soil river deposit, alluvium, and loam from decomposition of the rocks in place; usually very productive. Several small deposits of muck in different parts of the town, but not much employed as manure.

Estimate of crops, &c., by D. Baldwin, Esq. Hay, best farms, 2 tons per acre—average for whole town, one ton and a half; wheat 7 bushels; corn 30 to 40; oats 40; rye 25; barley and buckwheat, not estimated; potatoes 200; wool per sheep, 3 lbs.; butter per cow, 150 to 180 lbs. a year. Deeper ploughing would greatly improve the productiveness of the soil, especially where the soil is clayey.

MORETOWN. The rock in place is talcose slate, principally. A range of steatite occurs in the central part, accompanied with serpentine. The soil is mostly drift, except in the valley of the Winooski and Mad rivers. The alluvial and river deposits in these portions of the town are very productive. Small deposits of muck are found in several places, but have been little used.

Estimate of crops, &c., by Alpheus Bass, Esq. Hay one ton and a quarter per acre; wheat 10 to 12 bushels; corn 30; rye, barley and buckwheat, not grown; potatoes 200; wool 3 lbs. per sheep; butter 112 to 125 per cow, or cheese 250 lbs. a year.

MORGAN. This town lies in the calcareo-mica slate region. Rock in the eastern part, gneiss; soil, drift and alluvial, generally very productive when properly cultivated.

Estimate of crops, &c., by Rev. J. L. Clark. Hay, one ton and a fourth per acre; wheat 15 to 20 bushels; corn 40; oats 40 to 50; rye, none; barley 20; buckwheat 30 to 50; wool per sheep, 2 to 3 lbs.; butter per cow, 100 to 150 lbs. a year.

MORRISTOWN. Rock in place, talcose slate; soil, drift, river deposit and alluvial. Each of these varieties is of good quality, and the produce is large, generally. An extensive deposit of muck occurs near Joe's Pond, on the farms of Messrs. W. and L. Small and others. This pond, once doubtless covering a hundred acres

or more, is now reduced to two or three, and will eventually disappear entirely. The muck is very deep, and of excellent quality. Its value to the surrounding region cannot be easily estimated. Some smaller deposits are found in other parts of the town.

Estimate of crops, &c., by Hon. V. P. Noyes, J. Mills, Esq., L. Smalt, Esq., and Col. Herrick. Hay, one ton and a quarter to one and a half per acre; wheat 10 to 15 bushels; corn 40 to 50; oats 40 to 50; rye 20 to 30; buckwheat 30; potatoes 200; wool 3 lbs. per sheep; butter per cow, 100 to 140 lbs. a year.

NEWBURY. The rock is similar to other river towns. Soil, alluvial, river deposit and drift. The large amount of intervale has long rendered this one of the best agricultnral towns in the State. The proportion of valuable intervale is probably greater than in any other town; but its productiveness without manure has probably considerably diminished. The hills and banks near the river are gravel with subsoil of clay. Upland soil is good, and generally productive.

Estimate of crops, &c., by W. R. Shedd, Esq., aad Col. Tenney. Hay, one ton and a half per acre; wheat 15 to 20 bushels; corn 40; buckwheat 25 to 30; rye and barley, little grown; oats 40 to 50; potatoes 200; wool per sheep, 3 lbs.; butter per cow, 100 to 150 a year.

Estimate by H. Bailey, Esq., Great Oxbow. Hay 1 to 2 tons per acre; wheat 20 bushels; corn 40 to 50; oats 40, when not manured,—50 or more when land is manured. General course of cultivatiou:—1st, oats without manure, on green-sward. 2d, potatoes or corn, and twenty to thirty loads of manure. 3d, wheat or oats, and grass seed. Land usually remains in grass 8 or 9 years.

NEWFANE. The rock in this town is, in the east part, calcareo-mica slate, and talcose slate in the west part. Soil, gravelly loam. Deposits of muck in several places of good quality. Considerable interest has been excited in agricultural improvements. Compost manure used considerably. Ashes very valuable. Dressing of clay would be very valuable.

Estimate of crops, &c., by C. K. Field, Esq. Hay, rather less than a ton per acre; wheat 12 bushels; corn 30 to 40; barley 25 to 30; rye 10 to 15; wool per sheep, 3 lbs.; butter per cow, not estimated.

NORWICH. Rock clay slate and calcareo-mica slate. Soil, alluvium, river deposit and drift. Deeper ploughing is much needed, to improve the productiveness of the soil in this town. Muck exists in a few places in the north part of the town.

Estimate of crops, by Col. A. Stimson. Hay, one ton to ton and a quarter per acre; wheat 15 bushels, corn 25 to 30; rye

16 to 20; oats 30; potatoes 250; wool per sheep, 3 lbs.; butter per cow, 125, lbs., or cheese 250 a year.

Peacham. Rock calcareo-mica slate and granite. Soil deep loam, subsoil, generally rock. Several valuable and extensive deposits of marl are found. That on the farm of Mr. Johnson, is found below a bed of deep muck, and is eight or nine feet in thickness, and of good quality for making lime. Another large deposit is in Ladd's pond; smaller deposits occur elsewhere. In Hosmer pond, is a deposit of infusorial silica, estimated at more than 14,000 cords, though it would require millions of the animalcules, of whose shells it is composed, to form a mass of the size of a pea!

Peacham abounds in large deposits of muck. The 'great bog,' in the south west part of the town covers an area of more than 200 acres, and is probably twenty feet in thickness, and contains one and a half millions of cords. Other large deposits are found, like the meadow of Mr. Johnson, which will furnish an inexhaustible supply of the best of manure, for improving the fertility of the soil.

Estimate of crops, by Col. Wm. Wheeler, and Dea. E. C. Chamberlain. Hay, 1 ton per acre, best farms 2 tons; wheat 20 bushels per acre; corn 40; oats 30 to 40; barley, rye and buckwheat, but little grown; potatoes 300; wool per sheep 3 lbs.; butter per cow 100 to 150 lbs. a year.

It is very gratifying to learn, that there is an obvious improvement in the agriculture of this town, and that the interest is increasing.

Plymouth. Rock in this town, talcose slate and carbonate of lime. Soil, drift and decomposed rocks in place. Small tracts of alluvial soil near the pond and stream. A deposit of muck of good quality was examined on the farm of Rev. Mr. Baldwin, of six or eight acres, and several smaller deposits in other parts of the town, are said to be equally valuable.

Estimate of crops, &c. by Rev. Mr. Baldwin and others. Hay, 1 ton per acre; wheat 10 to 12 bushels per acre; corn 35 to 40; rye 15 to 20; buckwheat 35 to 40; oats 35; potatoes 250; wool, per sheep 3 lbs.; butter per cow, not estimated.

Putney. Bock clay slate, calcareo-mica slate and gneiss. Alluvial and drift soil. The intervals are very productive, and the town generally has a good soil. A very valuable muck bed on the farm of Mr. A. Keyes, contains ten or twelve acres; this has been "found as valuable as the best *barn manure.*" Some smaller deposits occur in other parts of the town, but not much used. Considerable interest exists with regard to agricultural improvements.

Estimate of crops by Dea. Crawford and others. Hay, 1 ton

and a quarter per acre; wheat, not much grown; corn 40 bushels; oats 40 to 50; rye 15; barley, none grown; potatoes 150 to 200; wool per sheep, 3¼ lbs.; butter per cow, no estimate.

Randolph. This town lies chiefly in the calcareo-mica slate region, and has many varieties of soil. On both the branches of White River, which passes through it, are considerable alluvial and river deposits. The central part has a deep and rich soil, formed of the decomposed rock in place and drift. Few towns are better adapted to agricultural purposes. Deeper ploughing and the application of clay to the gravelly tracts, occuring on the streams, would be greatly beneficial. Muck in small deposits is found in several places.

Estimate of crops, &c. by Wm. Nutting, Esq. Hay, 1¼ tons per acre; wheat 15 bushels; corn 40 to 50; oats 40; buckwheat 40 to 50; potatoes 250 to 300; wool per sheep, 3 lbs.; butter per cow, 100 to 150 lbs. a year.

Rochester. Rock in place, talcose slate, in which beds of serpentine and steatite occur. Soil mostly drift. Considerable tracts of alluvial land occur on the streams. Soil generally good, though the town is very uneven. Deposits of muck in a few places only.

Estimate of crops, &c. by Hon. E. D. Briggs. Hay, 1¼ tons per acre; wheat not estimated; corn 40; oats 40; buckwheat not estimated; potatoes 200; wool per sheep, 3 lbs.; butter per cow, not estimated.

Rockingham. Rock in place, calcareo-mica slate, and clay slate. Soil, alluvial, river deposits and drift. Intervals on the streams are valuable, and much of the land is adapted to agriculture. Beds of blue clay of considerable extent are found along the Connecticut River. Muck is found in a few places.

Estimate of crops on the interval. Hay 1½ ton per acre; wheat not often grown; corn 50 bushels; rye 15; oats 50; potatoes 225 to 250; wool per sheep, 3½ lbs.; land kept in grass three years, and then tilled three years.

Royalton. Rock in place, clacareo-mica slate. Considerable interval on White River and its branches, and portions of the upland are well adapted to agriculture. Other portions of the soil are liable to leach, and are not very productive without considerable manure. There is a large and very valuable deposit of marl on the farm of Mr. Dewey. It was deposited in an ancient beaver pond, and is now very accessible. It will supply lime for the whole White River valley. Several valuable deposits of muck are found in the vicinity.

Estimate of crops, by H. Bingham, Esq. and others. Hay, less than one ton per acre, best farms one ton and a half; wheat 12 to 15 bushels; corn 30; oats 25 to 30; buckwheat 20; rye

10; potatoes 150; wool per sheep, 3¾ lbs.; butter per cow, 75 to 100 lbs. a year.

RYEGATE. Rock calcareo-mica slate and granite. There is very little interval in this town; considerable deposits of brown and blue clay near the river. A very valuable deposit of muck occurs on the farm of J. Cameron and others, and many smaller deposits elsewhere. The land is generally uneven, but well adapted to grazing. Cows are the principal stock.* Deep ploughing has been proved exceedingly beneficial.

Estimate of crops, &c. by John Cameron, Esq. Hay, 1½ tons per acre; wheat 15 to 20 bushels, (considerable grown;) corn 25 to 30; barley, rye and buckwheat seldom grown; oats 40; potatoes 250; wool per sheep, 3 lbs.; butter per cow, 150 to 175 lbs. a year.

ST. JOHNSBURY, (East), and KIRBY. The range of clay slate found usually bordering on the Connecticut river, below the mouth of the Passumpsic, continues a northerly course through the west part of Waterford, east part of St. Johnsbury, and central part of Kirby, rising in high bluffs in these places. The other rocks are those common to the region. The soil, excepting small tracts of alluvial and river deposit, is drift of good quality. Muck is common in small beds, and is used much more than formerly.

Estimate of crops, by Seth Borroughs, Esq., Hon. C. Morrill, and Isaac Harrington, Esq. Hay, one ton per acre, — best farms, one and a half; wheat 15 bushels; corn 30; oats 30; buckwheat 30 to 40; potatoes 200; wool 2½ to 3 lbs. per sheep; butter per cow, 100 lbs. a year.

ST. JOHNSBURY, (Plain.) This town is in the calcareo-mica slate region. Being watered by the Passumpsic and Moose rivers, it has a considerable amount of alluvial and river deposits. The soil in the more elevated portions, is drift united with the decomposed rock in place, and is generally productive. It resembles very nearly the soil of other towns where blue limestone is the principal rock. A deposit of marl has recently been found on the farm of Hon. E. Paddock, from which a good quality of lime may be manufactured, for the supply of this portion of the State. Muck of good quality, occurs in many places, and is beginning to be employed to considerable extent. Interest in agricultural improvements is rapidly increasing.

Estimate of crops, by Joseph Fairbanks, Esq. Hay, one ton per acre—best farms, one and a half; wheat 16 to 18 bushels; corn 30 to 35,—river farms, 50 to 60; rye 10 to 12; oats 35; potatoes 150 to 200.

SOMERSET. Rock, Green Mountain gneiss. This is a hilly town, but has a good soil for grass, &c.

Estimate of crops, by H. Hall. Hay, one ton and a half per acre; wheat 20 bushels; corn 25 to 30; rye 20; oats 40; wool per sheep, 2½ to 3 lbs.; butter per cow, 100 to 125 lbs. a year.

STOCKBRIDGE. Rock, talcose slate. Soil, drift and some alluvium on the river, subsoil gravel.

Estimate of crops, by Dr. F. P. Fay, and —— Morgan, Esq. Hay one ton per acre; wheat 15 bushels; corn 30; rye 15; oats 35 to 40; potatoes 200; wool per sheep, 3 lbs.; butter per cow, 75 to 100 lbs. a year.

SPRINGFIELD. Rock in place, calcareo-mica slate principally. Soil, alluvial, river deposit and drift; generally well adapted to agriculture. Several beds of muck, very valuable. One on the farm of Dr. Chase, of several acres. A heavy dressing of clay on the sandy tracts near the Connecticut river, would be greatly beneficial. Beds of both brown and blue clay are frequent. The interest in improvements in agriculture is rapidly increasing in this town.

Estimate of crops, by E. Whitney, Esq., Dr. Chase and others. Hay one ton or less per acre; wheat 20 bushels, on the hills; corn 30 to 40; oats 40 to 50; potatoes 150, perhaps more; Many sheep kept, wool per head, (Saxony and Merino), 3 lbs.; butter per cow, 6 lbs. per week, or 120 lbs. a year.

STOW. This town is wholly in the talcose slate region; but a considerable portion was probably covered by the waters of an ancient lake, once existing between Mansfield, Sterling, and Worcester mountains. Much of the soil is alluvial or clayey. It is highly productive. Drift soil occurs in the more elevated portions, similar to that generally in the talcose slate region.

Estimate of crops, &c., by Noah Robinson, Esq., Nathan Robinson, Esq., and Dea. L. S. Bingham. Hay ton and a quarter to ton and a half per acre; wheat 15 to 20 bushels; corn 45; oats 35 to 40; rye 20; buckwheat 30 or over; potatoes 200 to 300; wool per sheep, 3 lbs.; butter per cow, 150 lbs. a year.

THETFORD. Rock, calcareo-mica slate. Considerable alluvial soil and river deposit on the Connecticut river, and drift on the Ompompanoosuck. Hill lands, deep loam generally. Small deposits of muck in several places, beginning to be used considerably by some.

Estimate of crops, by Mr. —— Hall, Union Village. Hay, one ton per acre; wheat 12 to 15 bushels; corn 35; oats 40; rye 15 to 20; potatoes 200; wool 2½ lbs. per sheep; butter per cow 100 to 120 lbs. a year.

* Mr. William Gibson emigrated to this town from Scotland in 1801, with seven sons, and was able to purchase only one lot of land, on which he settled. He deceased in 1845, at which time it was supposed that he and his descendants owned property to the value of half the town. This property has been acquired by agricultural industry, and chiefly from the profits of the dairy.

Townshend. The rock in this town is the calcareo-mica slate, and gneiss. Soil mostly drift, and loam from the decomposition of the rock, and usually of very good quality. On the river are narrow tracts of interval, and some deposits of clay, which will be of great value if applied to the sandy lands, as a dressing. Considerable muck occurs in small deposits.

Average of crops, &c., by Messrs. C. Gaffield, P. How, J. Jamieson, and Dr. Hyde. Hay one ton per acre; wheat, grown only on the hills, 15 to 25 bushels; corn 30 to 40; oats 40; rye 15 to 20; barley 20; potatoes 150 to 200; wool per sheep 3½ lbs. (native and Irish).

Troy. This town is long and narrow, lying in the Missisco valley. Rock, talcose slate, serpentine, and steatite. Soil, alluvium and drift, and of excellent quality. When under good cultivation it is very productive. Many deposits of muck occur, but none large, and not as yet much used.

Estimate of crops, &c., by E. Elkins, Esq., North Troy. Hay, best farms, 2 tons, average ton and a half; wheat 10 to 12 bushels; corn 40; oats 30 to 40; rye 25 to 30; buckwheat 50; potatoes 250; wool per sheep, 3 lbs.; butter per cow, 150 lbs. a year.

Tunbridge. This town is wholly in the calcareo-mica slate region. Considerable interval on the Branch, and some deposits of clay. Soil, generally drift and not very retentive; would be greatly improved by deeper plowing. A small deposit of marl, and several deposits of muck, occur.

Estimate of crops, by Orison Foster, Esq. Hay less than one ton per acre, best farms, ton and a half; wheat 12 to 15 bushels; corn 30; oats 35; barley 12; wool per sheep, 2¾ lbs; butter per cow, 75 lbs. a year.

Waitsfield. Rock in place, talcose slate. That part of the town lying in the valley of Warren river, has an excellent soil. It was doubtless, formerly covered by the waters of a lake that has entirely disappeared. Considerable quantities of muck exist near the river; also tracts of brown clay.

Estimate of crops, by Julian Dumas, Esq. Hay, one ton and a half per acre; wheat 12 to 15 bushels; corn 30 to 40; oats 35; rye, barley and buckwheat, little grown; potatoes 200; wool per sheep, 2½ to 3 lbs.; butter per cow 130 lbs. a year.

Walden. Rock in place, calcareo-mica slate. Soil, drift and loam from decomposed rock. A very valuable deposit of marl, on the borders of Lyford's pond, furnishes an excellent material for making lime, in any quantity required. There are many deposits of muck, and some of excellent quality, but little used as yet, except by a few farmers.

Estimate of crops, by L. Farrington, Esq. Hay, ton and a quarter to ton and a half per acre; wheat 15 to 20 bushels; corn 20; rye, none; oats 30 to 40; barley 25; wool per sheep 3½ lbs.; butter per cow 120 to 130 lbs. a year.

Wardsborough. Rock, Green Mountain gneiss. Soil, drift principally. The town is very uneven, but the soil retentive and produces good wheat and hay. Small deposits of black muck are frequent, which is used much more than formerly.

Estimate of crops, by John Tafts, Esq. Hay, one ton, perhaps less, per acre; wheat 15 to 20 bushels; corn 35; rye 15; oats 35 to 40; wool 3½ lbs. per sheep; butter per cow, 100 lbs. or over, a year.

Warren. Rock in place, talcose slate and Green Mountain gneiss. The soil is mostly drift, and of medium quality. Small deposits of muck occur, but have not been much improved as manure.

Estimate of crops, by W. Cardell, Esq., and others. Hay, one ton per acre; wheat 12 bushels; corn 25; oats 25 to 30; rye, buckwheat and barley, little grown: potatoes 130 to 150; wool 3 lbs. per sheep; butter per cow, 100 lbs. or more, a year.

Washington. Rock, calcareo-mica slate, and granite, very rapidly decomposing. Soil deep and rich in many places; in others, gravelly drift. The town is elevated and uneven. Deposits of muck not very large, nor frequent.

Estimate of crops, by G. R. Gale, Esq. Hay, one ton or less per acre; wheat 18 bushels; corn 25; oats 30; buckwheat 30; barley 25; potatoes 250; wool per sheep 3 lbs.; butter per cow 150 to 175 lbs. a year.

Waterbury. This town is principally in the talcose slate region; green mountain gneiss occurs in the west part. Soil, drift, river deposit and alluvium; the latter is considerable and of good quality; brown clay occurs near the streams in tracts of some extent. The town is well adapted to agriculture, being less broken than others in the vicinity. Several deposites of muck exist which are becoming more highly prized than formerly. Crops generally heavy.

Estimate of crops, &c. by J. Simpson, Esq. and others. Hay 1½ tons per acre; wheat, 20 bushels; corn 40; rye 25; oats 40; barley 30; buckwheat, 35; potatoes 200.

Waterford. Rock in place, calcareo-mica slate, clay and talcose slate. The soil near the stream is river deposit and drift; small tracts of interval are found in several places. The town is hilly, and the soil generally drift, of good quality. Several deposits of muck occur: some farmers are beginning to estimate as important sources of manure.

Estimate of crops, &c. by J. Works, Esq. Hay one ton per acre; wheat 15 to 20 bushels per acre; corn 30, (river farms probably 40); rye, buckwheat and barely not estimated; oats 30 to 40; potatoes 200 to 250; wool 2½ to 3 lbs. per sheep; butter per cow 100 lbs. a year.

WEATHERSFIELD. Rock, calcareo-mica slate, and gneiss. Soil, alluvium, river deposit and drift. The intervales are somewhat large and very productive. The upland generally has a good soil. The first uplifts from the intervales are sandy, and without admixtures of clay will not be very productive, but by the free use of clay may be made very valuable. I visited the farm of Hon. W. T. Jarvis, to whom, with many others who have kindly assisted me in my investigations, I am placed under many obligations. The farm of Mr. Jarvis, consists of 180 acres of intervale, 124 of plain, and the remainder, about 800 acres, of upland, lying farther back from the river. He has 350 acres of tillage land, under the plough and scythe. His annual crop is,—corn 1200 bushels; wheat 150 bushels; oats 1000; rye 100; potatoes 1000 to 1500; hay 250 tons. Average yield of wheat, 18 bushels per acre; corn 50; oats 70; hay one ton and a half per acre. He usually plants on green-sward, and sows grain and grass seed the next year, then mows three years. It is not so much the object of Mr. Jarvis to produce very large crops, as to obtain medium crops, with the least expense for labor &c. He applies thirty to forty loads of barn manure per acre, to land when planted, and three or four bushels of ashes to the grain crop. Mr. J. has done very much to improve the breed of sheep in this country. He first introduced the Merino, from Spain. While resident there, he purchased and sent five or six thousand to the United States. His present flock is one thousand, which yields, of the finest wool, 3¼ lbs. per sheep. Mr. J. has used considerable effort to introduce the Arabian breed of horses, as a cross with the native breed. He has some fine specimens in his stables, both for the saddle and harness.

WESTMINSTER. Rocks in place, clay slate, calcareo-mica slate; gneiss also occurs in the west part. Soil, alluvium, river deposit and drift. Below the loam on the upland, as I was informed by Hon. Wm. C. Bradley, is a stratum of gravel lying on blue clay and this resting on quicksand. Westminster will compare favorably with any town in this section of the country. It lies mostly on a plain, surrounded by semi-circular ranges of hills of moderate elevation; of these they are three ranges, parallel to each other, with considerable vallies between them—the western range is much the most elevated,—these ranges extend into Putney on the south and Rockingham on the north. Muck is considerably abundant and much used; a bed of marl, it is said, is found in the west part of the town, on the farm of Mr. Wilcox, but was not examined. Interest in agricultural improvement is rapidly advancing.

Estimate of crops, by John May, Esq. Hay 1½ tons per acre: wheat but little grown; corn 40 to 50 bushels; oats 40; rye 10 to 15; potatoes 200; wool per sheep 3 lbs., (Merino and Saxony); butter per cow not estimated.

WESTMORE. Rock, granite principally. Soil, drift. The town but sparsely settled. There is a deposit of infusorial silica south of the lake; muck of limited extent is found in several places.

Estimate of crops, &c. by S. Bishop. Hay 1¼ tons per acre; wheat 15 to 20 bushels; corn 30; oats 30; potatoes 150; wool per sheep 2½ to 3 lbs.; butter per cow 100 lbs. a year.

WILLIAMSTOWN. The rock in this town is calcareo-mica slate, very rapidly decomposing. Soil is deep, very productive and well adapted to wheat, grass, &c. The immense deposit of marl on the farm of Messrs. Kinsman, (probably the largest in the state not covered by water), will furnish an adequate supply of lime for the surrounding region, for many centuries. Many valuable deposits of muck are found in different parts of the town.

Estimate of crops, by Mr. Kinsman and E. Gale, Esq. Hay 1½ tons per acre; wheat 16 to 20 bushels; corn 35 to 40; oats 30; barley not much grown; buckwheat 40; potatoes 200—many are grown for making starch; wool per sheep 3 lbs.; butter per cow 100 to 125 lbs. a year.

WINDHAM. Rock, generally talcose slate. Soil mostly drift. The town is hilly, and the soil generally retentive. Muck deposits not frequent.

Estimate of crops, &c. by Rev. Mr. Arms. Hay one ton per acre; wheat 12 to 15 bushels; rye not grown; corn 30; oats 36; potatoes 250; wool per sheep 3 to 3½ lbs. (native and Merino); butter per cownot estimated.

WINDSOR. Rock in place, calcareo-mica slate and clay slate. Soil alluvial, river deposit and drift. The amount of inverval is not large; many beds of clay occur which might be very advantageously applied to the gravely soil, on the first uplifts from the intervals. In the west part of the town a good deposit of marl was examined on land of Mr. Samuel Myrick; it contains some two acres; another deposit, it is said, is found in the same neighborhood. Muck is found in the west part of the town, in many places.

No estimate of crops was received.

Agricultural productions will compare favorably with other towns in the vicinity;—corn and oats, probably 50 bushels each; hay one ton and a half per acre.

WOODBURY. This town is in the calcareo-mica slate region. A range of granite passes through it. Soil, drift and decomposed rocks in place;—the surface is uneven. It contains numerous ponds, on the borders of which are large supplies of muck.

Estimate of crops, &c. by Mr. Cilley. Hay 1½ tons per acre; wheat 12 bushels; corn 30; rye 10 to 12; oats 30 to 35; barley 20; potatoes 200; wool per sheep 3 lbs; butter per cow 100 lbs. a year.

WOODSTOCK. Rock, calcareo-mica slate. Soil, gravelly loam or drift generally; some tracts of alluvium on the river are of good quality. There is a very valuable deposit of marl on the farm of Hon. C. Marsh, covering twelve to fifteen acres; the marl is probably six to ten feet deep, lying beneath muck. Here was a small natural pond, very much enlarged doubtless by a beaver dam; the muck is three or four feet in depth 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; other deposits of muck of smaller extent occur. Visited the farm of Mr. Cushing, one mile east of the village, consisting of twenty-five acres of interval, and two hundred and seventy-five of upland. Mr. C. purchased of this farm one hundred acres twenty-one years ago, and was able to pay only a fourth part of the value; it was in a very impoverished state. He has since added two hundred acres adjoining, and purchased a back farm and pasture, and has brought the whole into a high state of cultivation and now keeps a flock of five hundred and fifty sheep, beside other stock;—he has erected barns and other buildings adequate to the exigencies of the farm—thus developing a specimen of thrift and agricultural enterprise, very instructive to the young men of the State. Mr. C. makes it an object to raise wool of the best quality. Average of hay, one and a half tons per acre. He succeeds well with winter wheat and obtains twenty bushels per acre; corn thirty to fifty.

WOLCOTT. Rock, talcose slate. Soil, drift, river deposit and narrow tracts of alluvium on the streams. Small deposits of muck were noticed.

Estimate of crops, &c. by R. Hutchins and J. Hutchins, Esq. Hay one ton per acre; wheat 12 to 15 bushels; corn 30 to 40; oats 30 to 40; barley, buckwheat and rye seldom grown; potatoes 150; wool per sheep 3 lbs.; butter per cow 100 to 150 lbs. a year.

WORCESTER Rock in place, talcose slate. The town is very hilly and broken. Soil on the streams generally drift and alluvium of good quality. One very large deposit of muck, and others smaller occur, not however much used as manure.

Estimate of crops by Mr. Rice, and Milton Brown, Esq. Hay one and a fourth to one and a half tons per acre; wheat 12 to 15 bushels; corn 30 to 35; barley 30; buckwheat 30; Rye not cultivated; potatoes 200 to 300 per acre; wool per sheep 2½ to 3 lbs.; butter per cow 120 a year.

Remarks. In giving the estimate of crops, &c., when different individuals in any town disagreed with each other in amounts, the lowest and highest are usually stated.

Inquiries have been extended to the methods adopted for preserving manure, especially the urine of cattle, by the construction of cellars under stables. Such means have been provided in only a few instances in that part of the State which I have visited. This is inexplicable, as but few intelligent farmers are ignorant of the fact that *urine* has greater fertilizing properties than solid manure. The expense of the construction of such cellars is so little, and as common soil, when dried and placed in such cellars, during the winter, (when muck cannot be obtained for that purpose,) is worth quite as much as manure from stable windows, it is surprising that so few have been constructed. This neglect has doubtless been attended with a loss of many hundred thousand dollars to the people of the State, in the value of agricultural products that might have been secured. The exposure of manure, thrown from stables, to the influence of the sun and rains, without covering, occasions a great waste of the fertilizing salts contained in it, especially ammonia. The value of manure, protected from the weather, is nearly twice as great, as when exposed in the usual manner. Ample means are available, to most of those making agriculture their business, for augmenting the produce of land, now under cultivation, 50 or 100 per cent. The great difference observable in the crops of farms similar in soil, &c., justifies this conclusion. Attention to this subject is increasing, but far less so than true economy demands of a people proverbial for economizing in most other respects.

By the analyses of different kinds of grain,&c., the importance of certain elements in the soil is made apparent. The following analyses of the more important grains, also of the various kinds of manure, that may be most readily applied as fertilizers, will be conducive to the objects contemplated by the department of the geological survey assigned to me. These analyses of grains and straw are taken from Sprengel. The figures in the several columns indicate the number of pounds contained in one thousand pounds of the articles named in the first column.

	Potassa.	Soda.	Lime.	Magnesia.	Alumina.	Oxide of Iron.	Oxide of manganese.	Silica.	Sulphuric acid.	Phosphoric acid.	Chlorine.
Wheat,	2.25	2.40	0.96	0.90	0.26			4.00	0.50	0.40	0.10
Barley,	2.78	2.90	1.06	1.80	0.25			11.82	0.59	2.10	0.10
Rye,	5.32		1.22	0.44	0.24	0.42	0.34	1.64	0.23	0.46	0.09
Oats,	1.50	1.32	0.86	0.67	0.14	0.40		19.76	0.35	0.70	0.10
Beans,	4.15	8.16	1.65	1.58	0.34			1.26	0.89	2.92	0.41
Peas,	8.10	7.39	0.58	1.36	0.20	0.10		4.10	0.53	1.90	0.38
Potatoes,	40.28	23.34	3.31	3.24	0.50	0.32		0.84	5.40	4.01	1.60
Wheat Straw,	0.20	0.29	2.40	0.32	0.90			28.70	0.37	1.70	0.30
Barley "	1.80	0.48	5.54	0.76	1.46	0.14	0.20	38.56	1.18	1.60	0.70
Oat "	8.70	0.02	0.52	0.23	0.06	0.02	0.02	45.88	0.79	0.12	0.05
Rye "	0.32	0.11	1.78	0.12	0.25			22.97	1.70	0.51	0.17
Bean Stalks,	16.56	0.50	6.24	2.09	0.10	0.07	0.05	2.20	0.34	2.26	0.80
Pea "	2.35		27.30	3.42	0.60	0.20	0.07	9.36	3.37	2.40	0.04
Potato "	81.90	0.90	129.70	17.00	0.40	0.20		49.40	4.20	19.07	5.00
Rye hay,	8.81	3.94	7.34	0.90	0.31			27.72	3.53	0.25	0.06
Red clover hay,	19.95	5.29	27.80	3.33	0.14			3.61	4.47	6.57	3.62
White " "	31.05	5.79	23.48	3.05	1.90	0.63		14.73	3.53	5.05	2.11
Lucerne, "	19.40	6.15	48.31	3.48	0.30	0.30		3.30	4.04	13.07	3.18

By computing the weight of the grains, straw or hay removed from an acre of land each year, it will be easy to ascertain the quantity of potassa, soda, lime, &c. taken from the soil of that acre by any given crop. If an acre of wheat yield twenty five bushels, the weight of grain will be 1500 lbs. ; and the straw about twice as much, say 3,000. Of course one and a half times as much potassa, &c. will be taken from the land as the amount in the table against wheat, and three times as much as the amount in the table against the straw of wheat. Thus, if an acre of red clover yields two tons (4,000 lbs.) the soil of that acre loses 79.80 lbs. of potassa, 21.16 lbs. of soda, 111.20 lbs. of lime, 26.28 lbs. of phosphoric acid, and 17.88 lbs. of sulphuric acid, &c. each year.

The analyses of various kinds of manure, which we shall subjoin, will show the value of them as fertilizers of the soil.

Notwithstanding the diversity of soils in this State, and the fact that some are much better adapted to the purpose of agriculture than others, it is yet doubtless true, that the amount of the produce of the soil depends as much, not to say more, on the manner of tillage and the character of manures. As all soils, even the richest, must diminish in strength by the removal of crops, as just explained, it becomes a question of the highest importance, what are the most economical fertilizers that can be applied? To answer this question accurately, is not possible without some knowledge of the character of the soil in a particular section or district. In some places the application of wood ashes may be of very essential service, while in others of but little. In some districts, gypsum may for a time be found highly valuable, but in others of no value at all. The application of shell-marl may be greatly beneficial to soils, where there is a deficiency of carbonate of lime, but of no service where this exists sufficiently already. But while these facts are admitted, it is doubtless equally certain that the sources of manure available to every farmer, are, through the benevolence of Providence, adequate to the wants of every variety of soil in Vermont. It may be true economy to expend twenty dollars to purchase and transport a ton of plaster of Paris, to apply to a given farm, but is doubtless true that fertilizing substances of greater value than this, to that particular farm, often are allowed to waste, to save or preserve which, would cost much less. It is doubtless capable of practical demonstration, that every acre of arable land in the State, may be made highly productive by the application of the manures, available to every farmer on his own premises. The native soil of the State will not probably suffer by comparison with any other,—the natural resources for manure are probably not exceeded, if equalled by any other ;—these resources are to a great extent so distributed as to be conveniently available in a very large proportion of that part which has been examined the present season; but the writer has been forced to believe that these advantages, great as they are, are less than those which would be secured by saving and applying the fertilizing substances now almost entirely lost. If the urine of the cattle in the State, and the valuable liquid manures of the houses were preserved and applied to the soil in a proper manner, there can be no reasonable doubt that the land now under the scythe and plough, would yield double the present amount of produce.* If this be true, or if only half that increase might be realized, the benefits of rail-roads to the State, great as they doubtless may be, will be far less than those which would follow the saving and applying such manures. Agriculture is the great interest of the State. The capital invested in it is many times greater than the amount invested in any thing else. Improvement here, is therefore, of more consequence than elsewhere. When improvement can be effected without a heavy expenditure of capital,—when to provide for saving twenty dollars will cost but five, and this not money, but labor; surely information how to do it, can hardly be valued too highly by any people entertaining just views of political economy.

It may be important as a means of making the following analyses better understood by those not familiar with chemical terms, to remark that Urea, which is found so abundant in urine, consists of carbon, 20.0 per cent.; hydrogen, 6.6 per cent.; nitrogen, 46.7 per cent.; oxygen, 26.7 per cent.

"It is therefore far richer, as a fertilizer, than animal flesh, or blood, or any of those other richly fertilizing substances, of which the main efficacy is supposed to depend upon the large proportion of nitrogen they contain."

Urea possesses an other remarkable property; during the fer-

Waste of urine. "The great quantity of solid matter contained in the recent urine voided in a year by a man, a horse, and a cow, and the weight of ammonia they are respectively capable of yielding may be represented as follows:—

	Quantity of urine.	Solid matter.	Containing of urea.	Yielding of ammonia.
Man,	1,000 lbs.	67 lbs.	30 lbs.	17 lbs
Horse,	1,000	60	?	?
Cow,	13,000	900	400	230

How much of all this enriching matter is permitted to run to waste? The solid substances contained in urine, if added to the land, would be more fertilizing than guano, which now sells at $44.40 a ton. If we estimate the urine of each individual on an average at only 600 lbs., then there are carried into the common sewers of a city of 15,000 inhabitants, a yearly weight of 600,000 lbs., 270 tons of manure, which, at the present price of guano, is worth $11.988.00, which would, no doubt, prove more fertilizing than its own weight of guano, and might be expected to raise an increased produce of not less than 9,000 bushels of grain."—Prof. Johnston's Lectures.

mentation of urine, it changes entirely into the "carbonate of ammonia. It hardly need be said that ammonia is one of the most fertilizing agents applied to soils." The efficacy of urine as a manure, depends upon the quantity of solid matter which it holds in solution, and upon the nature of this solid matter, and the change which the organic part is known to undergo. The following table by Prof. Johnston, exhibits the average proportions of water, and of the organic and inorganic matters contained in the urine of man and other animals, in their healthy state, and the average quantity voided by each in twenty-four hours.

Urine of	Water in 1000 parts.	Solid organic matter in do.	Solid inorganic matter in do.	Total.	Amount voided in 24 hours.
Man,	969	23.4	7.6	31	3 lbs.
Horse,	940	27.	33.	60	3 lbs.
Cow,	930	50.	20.	70	40 lbs.
Swine,	926	56.	18.	74	?
Sheep,	960	28.	12.	40	?

The above table will show, that the urine of the cow, by the quantity of solid matter it contains, is much more valuable than that of any other domestic animal, on account of the greater quantity voided, and its richness in fertilizing salts.

Berzilius found human urine to contain in 1000 parts,

Water,	933.0	Phosphate of soda,	2.9
Urea,	30.0	Phosphate of ammonia,	1.6
Uric acid,	1.0	Common salt,	4.5
Lactic acid, lactate of ammonia,	17.1	Sal ammonia,	1.5
Sulphate of potassa,	3.1	Phosphate of lime, magnesia, &c.	1.1
Sulphate of soda,	3.2		

Sprengel, who has very carefully analyzed the urine of cattle, finds it to contain in 1000 parts; the first column shewing an analysis of fresh urine, and the second, of urine mixed with an equal quantity of water and allowed to ferment four weeks in open air.

Water,	926.2	934.8
Urea,	40.0	6.0
Mucus,	2.0	0.3
Hippuric and lactic acid,	6.1	6.2
Carbonic acid,	2.6	15.3
Ammonia,	2.1	16.2
Potassa,	6.6	6.6
Soda,	5.5	5.6
Sulphuric acid,	4.0	3.3
Phosphoric acid,	0.7	1.5
Chlorine,	2.7	2.7
Lime,	0.6	trace.
Magnesia,	4.0	4.0
Alumina, Oxide of iron and Oxide of manganese,	0.1	—
Silica,	0.4	0.4

It will be seen that when fermented, the quantity of urea is greatly diminished, while carbonic acid and ammonia are greatly increased. The former is converted into the latter. When urine* is allowed to unite with brown muck, or with dry earth placed in a cellar under the stable, fermentation takes place and the ammonia is mostly absorbed and preserved by the muck or earth, and may be easily applied to the soil. Straw, &c. placed in such a cellar will absorb and take up a less quantity of the ammonia of the urine. It becomes, however, a valuable manure, when allowed to remain sufficiently long to become thoroughly rotted or decomposed. Mr. Penot found in 100 parts of fresh cow dung,

Water,	69.58	Carbonate of lime,	0.24
Bitter matter,	0.74	Sulphate of lime,	0.25
Sweet substance,	0.93	Phosphate of lime,	0.46
Chrophylle,	0.28	Carbonate of iron,	0.09
Albumen,	0.63	Woody fibre,	26 39
Muriate of soda,	0.08	Silica,	0.14
Sulphate of potash,	0.05	Loss,	0.14
			100.00

"In 100 lbs. of cow dung, scarcely one-sixth is of any value in agriculture." The ammonia contained in both the liquid and solid manures of the barn, being exceedingly volatile, mostly evaporates, and so passes into the air, where exposed to the action of the wind, &c. All manures, should therefore, as far as possible be protected in barn cellars or by sheds, by which great loss will be prevented.

S. R. HALL.

Craftsbury, Sept. 10, 1846.

* Dr. Samuel L. Dana, of Lowell, to whose experiments on various manures, agriculture is greatly indebted, remarks,—" Let this [urine of cattle] now be compared with the value of cow dung. One hundred lbs. of cow dung contains two lbs. of carbonate of ammonia; one hundred lbs. of urine contains four lbs. of ammonia in its urea, besides that in its other ammoniacal salts. The quantity of liquid manure produced by one cow annually, is sufficient to fertilize one acre and a fourth of ground, producing effects as durable as the solid evacuations. A cord of loam saturated with urine is equal to a cord of the best rotted dung. If the liquid and solid evacuations, including the litter are kept separate, and soaking up the liquid by loam, it is found they will manure land in proportion by bulk of seven liquid to six solid, while their actual value is two to one. One hundred lbs. of cow's urine affords about eight lbs. of the most powerful salts that have ever been used by farmers." It is more important "to save the last than the first." "Let both be saved." "Grass land saturated with urine only, yields nearly double, to that not so manured." Muck saturated with urine, as a top dressing for grass lands is invaluable.

MINING.

ORES OF IRON.

Brown Iron Ore. Bennington. We have been informed that a new bed of brown ore has been discovered and opened in the north-east corner of Bennington, and that the furnace operations in this town have produced eight to ten tons of iron daily. Not having been able yet to examine the ore beds of this town in person, I subjoin an extract from a letter of Professor Dewey respecting the ore bed near the furnace:

"I think it is some rods in width. On the west side of it lies a bed of manganese [some] rods wide, if I was told right, and separated from the iron ore, where I saw it, by a mere layer of clay, often not half an inch thick. When Mr. Trenner worked that furnace, 25 years ago perhaps, he told me, that on finding that black pure manganese, he put a large quantity into the furnace, to get better iron from this purer ore as he thought it; that when they tapped the furnace, the liquid stream took fire and burned with fury in all directions, driving all the hands from the building, so that it was not possible to proceed, till the manganese was removed from the furnace, at no little expense."

The reason of this is obvious, for it was, on a larger scale, the common chemical experiment of disengaging from the manganese ore by heat a quantity of oxygen gas, and immersing in the gas a heated iron wire or watch spring, which then burns with great fury.

Wallingford. The "black ore" and alloy of iron and manganese made from it, which we mentioned in the last Report, have been analyzed by Mr. Olmsted, with the following results:

"Black Ore."		Alloy.	
Peroxide of Iron,	71.30	Metallic Iron,	88.71
" " Manganese,	12.93	" Manganese,	11.28
Alumina,	trace.		99.99
Silica,	3.00		
Water,	12.50		
	99.73		
Metallic Iron,	49.34		

The proportion of metallic iron and manganese in the specimen analyzed was, iron 84.57, and manganese 15.43. But the composition of the ore is not uniform.

Chittenden. A specimen taken from the solid ore bed, (see page 20, of last Report,) and certified to by the overseer of the works as an average specimen, and a specimen of the mammillary siliceous brown ore, mentioned on page 29 of the same Report, were analyzed by Mr. Olmsted, with the following results:

	Solid ore bed.	Siliceous ore.
Peroxide of Iron,	84.90	37.81
Alumina,	.47	trace.
Silica,	.75	55.81
Water,	13.88	6.38
	100.00	100.00
Metallic Iron,	58.66	26.84

The solid bed of ore, described in the former Report, has supplied Mr. Granger's furnace since that time, and has been found to be 12 feet in thickness. The easterly margin of the north end has been reached, where it rests on decomposed rocks, but no southerly termination has been found. Dr. Ewing, who has given much attention to this mine, is of the opinion that this mass, enormous as it is, is only a portion of a still more extensive solid bed of ore.

Salisbury. There is some reason to suppose that a bed of ore exists near the north end of Lake Dunmore, according to the testimony of Mr. Dewey, who gave me specimens of good brown ore, which he said were found with many others within the space of a few acres.

Colchester. The ore bed mentioned in the last Report has since been opened with results justifying the encouragements then held out. A specimen has been analyzed by Mr. Olmsted as follows:

Peroxide of Iron,	91.50
Water,	11.32
	102.82

The specimen, therefore, appears to have been absolutely pure ore, containing about 61 per cent. of metallic iron.

A mass of sand near Clay Point, which has been consolidated by hydrated iron and manganese, has attracted some attention, but it affords only slight ground for the expectation of finding workable ore.

Plymouth. Tyson's furnace, in the extreme south part of Plymouth, is supplied with ore from a bed one-fourth of a mile to the north-west. This ore cannot be distinguished from the Taconic brown ore of the west side of the mountains, and like that is more or less mixed with psilomelane (Manganese ore,) which occurs either in mammillary coatings, or intimately mixed with the iron ore. Mr. Jocelyn informed us that a solid mass of ore had recently been reached, of unknown extent, but the works at the time of our visit were not in a condition for satisfactory examination.

Waterford. Some small isolated beds of bog ore have been found in the vicinity of the furnace of St. Johnsbury, and nearly exhausted. One on the land of Mr. Timothy Goodale yielded a few hundred tons.

Magnetic iron ore. Colchester. In the form of iron sand, a considerable quantity occurs on the sand beach next north of Clay Point. If the demand were sufficient, a small boat load might easily be obtained by visiting this place and Chimney Point and other localities on the Lake shore.

Troy. The titaniferous magnetic ore of this town occurs in the east range of serpentine, east of the Missisco River. It is a nearly perpendicular vein, which conforms in direction to the general direction of the serpentine range, and has been traced with more or less interruption for the distance of two miles. It is from three to five feet wide, and does not appear to be in danger of being exhausted in the direction of its length or depth. Yet, although far more regular than is common in the serpentine minerals, its interruptions shew that it is not entirely in theory an exception to the general rule, and other irregular veins and masses of ore conform to the general fact.

In 1844, 600 tons of pig iron and castings were made, and machinery has since been erected for the manufacture of wrought iron also. The ore is quite free from admixture with the serpentine. We subjoin an analysis of a specimen by Mr. Olmsted.

Peroxide of iron,	81.20
Protoxide "	13.37
Titanic acid,	4.10
Silica,	1.33
	100.00
Metallic iron,	66.62

Crystals of magnetic ore are more or less abundantly disseminated through a great part of the talcose slate rocks, and in several instances have been the occasion of expense in exploration without sufficient reason. Thus in the north part of Bristol, on the hill east of the residence of Judge Holley, $100 have been expended in the excavation of nearly perpendicular strata of talcose slate, through which were abundantly disseminated small octahedral crystals of magnetic iron ore. In such cases the crystals appear to have resulted from metamorphic agency on the ferruginous particles originally deposited with the strata, for the distribution of them in greater or less abundance coincides with the stratification, and there is no such thing as a vein of them crossing the strata, but of two adjacent strata one may be densely filled with them and the other quite destitute. If this view be correct, we can easily see why so large a portion of the Green Mountain range and other extensive regions should abound with these crystals, without being accompanied by proper veins of magnetic ore, which is regarded by many geologists, when occurring in true veins, as an igneous rock erupted through other rocks from a deep-seated source.

In the east part of MIDDLEBURY, high up on the Green Mountains, on land of Mr. Allen Foote, some strata have been discovered, which contain an unusually large proportion of these crystals, and which therefore might be advantageously used in mixture with a richer ore. In the neighborhood of the numerous existing forges, which use the rich ores of New York, such strata may possibly be made of some account.

PLYMOUTH. Nearly a mile south of the source of Black River, and near the middle of the town, is the vein of magnetic ore, belonging to Mr. Taylor, in a talciferous quartz rock. A considerable quantity of ore has been removed, but on account of its irregularity, it is not now worked. Specimens may be obtained which have polarity.

Specimens from the locality of magnetic and of *specular iron ore*, which was described in the last Report, have been analyzed by Mr. Olmsted.

Crystals of magnetic ore and a gangue of siliceous specular ore in which they were imbedded, and a specimen of the specular ore were separately analyzed.

	Crystals.	Gangue.	Specular ore.
Peroxide of iron,	73.82	15.00	99.89
Protoxide "	26.18	——	——
Silica,	trace	76.00	trace
Water,	——	9.00	——
	100.00	100.00	99.89
Metallic iron,	72.03	10.40	69.26

A mile and a half south of the the north line of the town, in the same limestone valley, a granular specular ore occurs irregularly in the limestone. Specimens of great beauty and purity are obtained, but it is doubtful whether it occurs in any workable quantity.

CHITTENDEN. On pages 26 and 27 of the last Report we described an example of octahedral pseudomorphous crystals of specular iron imbedded in granular specular iron. From further examination and from the analyses by Mr. Olmsted, we find those views confirmed, and it is also a fact of no small interest that many, probably a large majority of the smaller crystals are unaltered magnetic ore, while others are more or less deficient in the protoxide, exhibiting, in constitution and in the color of the streak in various specimens, a gradation from the magnetic oxide to the peroxide, without change of form.

Mr. Olmsted first operated on some of the smaller crystals, which had a black streak, and found the ordinary composition of magnetic ore. A larger crystal, with a reddish black streak, distinctly magnetic, "shewed but a feeble trace [of the protoxide of iron] in a large amount of the solution."

Another of the larger crystals, with a red streak, and feebly magnetic, "gave with the usual test no indication of protoxide of iron.

A similar case of pseudomorphism, by chemical change of crystals of magnetic ore to the peroxide, is described by Professor Emmons, as occuring at the Saxe ore bed, near the village of Crown Point. (Geol. Rep., N. Y., p. 235.) This and several other examples are described in the Trans. Am. Assoc. of Geologists, I, 251.

FRANKLIN COUNTY, AND MILTON. The following are the analyses by Mr. O. of two specimens from Milton and one from Fairfield, from the localities described in the last Report.

	Milton.	Milton.	Fairfield.
Peroxide of iron	98.30	98.22	95.71
Protoxide "	97	——	trace.
Peroxide of manganese,	trace	——	——
Silica,	91	1.78	3.91
	100.18	100.00	99.62
Metallic iron,	69.00	68.10	66.36

To the localities of this ore described by Messrs. Thompson and Hall the last year, we have to add one in ENOSBURGH, where an irregular bed, more or less mixed with the talcose slate, a few feet in thickness, occurs three-fourths of a mile south of the centre of the town.

In BERKSHIRE, between the west village and the west line, at the road side, is a talcose rock through which are abundantly disseminated particles of specular ore. Mr. O.'s analysis shews the following results.

Peroxide of iron,	44.01
Insoluble residue,	46.39
Lime, magnesia and loss,	9.60
	100.00
Metallic iron,	28.27

In connection with the richer ores in the immediate vicinity, this rock may perhaps be used to advantage as a flux.

We have examined several localities, in which the red oxide of iron exists in small quantities, and without indications of greater quantity, but it is unnecessary to describe them.

CHROMIC IRON.

The exploration of the serpentine ranges in the vicinity of the head waters of the Missisco river has realized the anticipations expressed last year.*

JAY. In the east part of this town, about sixty rods west of the middle of the east line is a serpentine range, on land of Enos Farwell, where our attention was called to some "iron ore," which proves to be chromic iron ore of excellent quality, within three rods of a good road and near water power.

It occurs in veins somewhat irregular, of which the largest is from one to two feet wide, and we were assued by Mr. F. that it also occurred at a spot some thirty rods north, which we perceived to be in the direction of the vein, but the circumstances of our visit prevented farther exploration. The great importance of this discovery was readily understood, and several individuals have followed up this with additional discoveries, of which we are unable at present to give a description. The principal vein which we examined in person, now belongs, as we are informed, to W. W. Huse Esq., whose skill and enterprise, so advantageously exhibited in the mangement of the Troy furnace, may be expected to render the ore available.

A partial analysis has been made by my friend and college associate, Professor Twining, who has made 180 grains of chrome yellow from 100 of the ore, without exhausting the chromic oxide of the latter: the appearance and specific gravity indicate its richness.

WESTFIELD. We have examined the locality mentioned by Mr. Hall last year, and find a small irregular vein, which does not indicate any thing conclusive on the workable value of the ore.

There appear to be various compounds of the oxide of chrome with peroxide of iron and with alumina, as may be seen in the following list of analyses.

*When our extensive ranges of serpentine rock shall be thoroughly explored, we may hope for valuable discoveries of this mineral.—*Geo. Rep. of* 1845, *p.* 27.

Analyst.	Locality.	Oxide of chrome.	Peroxide of iron.	Alumina.	[Silex.	Manganese.
Thomson;	Shetland;	56.00	31.00	13.00		
Laugier;	Siberia;	53.00	34.00	11.00	1.00	1.00
Seybert;	Chester, Ms.;	51.56	35.14	9.72	2.00	trace.
Klaproth;	Krieglock;	55.50	33.00	6.00	2.00	"white
Bertheir;	St. Domingo;	56.00	37.00	21.50	5.00	sub-
Vauquelin;	Var, France;	53.70	34.70	20.30	2.00	stance."
Thomson;	Baltimore;	52.95	29.24*	12.22	trace	3.09
Beudant;	Baltimore;	39.50	36.00	13.00	10.6	magnesia.
Beudant;	Roeras;	54.08	25.66	9.00	4.83	5.36
Abich;	?	60.04	20.13	11.85		7.45

From the imperfect analysis made of the Jay ore, we may hope that it will prove to be one of the richer varieties.

This ore much resembles in structure and color the magnetic iron ore, but it is easily distinguished by a very feeble or no magnetism; by the brown streak (powder); and by the beautiful emerald green glass obtained by fusion of a small fragment in borax, the glass by a similar process with magnetic iron ore being of a dingy olive or bottle green.

Since 100 grains of the pure mineral will yield about 225 grains of chrome yellow, we may in anticipation of an analysis, perhaps safely reckon that this ore will give double its weight of chrome yellow, and since this is worth about $600 per ton, a ton of the best of the ore will produce about $1200. But it must be remembered that the cost of raising the ore is one of the least of the expenses of the manufacturer, as may be seen from the fact that in manufacturing one ton of the ore, about 2786 lbs. of nitre, and 5230 lbs. of sugar of lead would be requisite for the product above mentioned. This estimate supposes no waste of any of the materials, being based on their chemical equivalents. Probably a considerable excess of the ore would prevent any great waste of the more costly materials.

The substitution of potash and peroxide of manganese, both of which may be obtained within the State at a very low price, in the place of nitre, may considerably reduce the expense. The present market value of good ore is $40,00 per ton.

In order to shew the uses of an ore, which is likely to be found abundantly in the region above mentioned, but with which our community in general is but little acquainted, I have thought it expedient to subjoin the following rather long extracts from a work, which should be in the hands of every person engaged in mining or manufactures, "Ure's Dict. of Arts, Manufactures, and Mines."

*" Protoxide "?

"The chief application of this ore is to the production of chromate of potash, from which salt the various other preparations of this metal used in the arts are obtained. The ore, freed, as well as possible, from its gangue, is reduced to a fine powder, by being ground in a mill under ponderous edge-wheels, and sifted. It is then mixed with one third or one half its weight of coarsely bruised nitre, and exposed to a powerful heat, for several hours, on a reverberatory hearth, where it is stirred about occasionally. In the large manufactories of this country, the ignition of the above mixture in pots is laid aside, as too operose and expensive. The calcined matter is raked out, and lixiviated with water. The bright yellow solution is then evaporated briskly, and the chromate of potash falls down in the form of granular salt, which is lifted out from time to time from the bottom with a large ladle, perforated with small holes, and thrown into a draining-box. This saline powder may be formed into regular crystals of neutral chromate of potash, by solution in water and slow evaporation; or it may be converted into a more beautiful crystalline body, the bichromate of potash, by treating its concentrated solution with nitric, muriatic, sulphuric, or acetic acid, or, indeed, any acid exercising a stronger affinity for the second atom of the potash than the chromic acid does.

Bichromate of potash, by evaporation of the above solution, and slow cooling, may be obtained in the form of square tables, with bevelled edges, or flat four-sided prisms. They are permanent in the air, have a metallic and bitter taste, and dissolve in about one tenth of their weight of water, at 60° F.; but in one half of their weight of boiling water. They consist of chromic acid 13, potash 6; or, in 100 parts, 68·4+31·6. This salt is much employed in calico-printing and in dyeing.

Chromate of lead, the chrome-yellow of the painter, is a rich pigment of various shades, from deep orange to the palest canary yellow. It is made by adding a liquid solution of the neutral chromate (the above granular salt) to a solution, equally liquid, of acetate or nitrate of lead. A precipitate falls, which must be well washed, and carefully dried out of the reach of any sulphuretted vapors. A lighter shade of yellow is obtained by mixing some solution of alum, or sulphuric acid, with the chromate, before pouring it into the solution of lead; and an orange tint is to be procured by the addition of subacetate of lead, in any desired proportion.

For the production of chromate of potash from chrome ore, various other processes have been recommended. The followiug formulæ, which have been verified in practice, will prove useful to the manufacturers of this important article:

I. Two parts of chrome ore, containing about 50 per cent. of protoxide of chromium:
   One part of saltpetre.

II. Four parts of chrome ore, containing 34 per cent. of protoxide of chromium.
   Two parts of potashes.
   One part of saltpetre.

III. Four parts chrome ore, — 34 —
   Two of potashes.
   Four tenths of a part of peroxide of manganese.

IV. Three parts of chrome ore.
   Four parts of saltpetre.
   Two parts of argal.

Some manufacturers have contrived to effect the conversion of the oxide into an acid, and of course to form the chromate of potash, by the agency of potash alone, in a calcining furnace, or in earthen pots fired in a pottery kiln.

After lixiviating the calcined mixtures with water, if the solution be a tolerably pure chromate of potash, its value may be inferred, from its specific gravity, by the following table:—

At specific gravity	1·28	it contains about 50	per cent. of the salt.
	1·21	33	
	1·18	25	
	1·15	20	
	1·12	16	
	1·11	14	
	1·10	12	

In making the red bichromate of potash from these solutions of the yellow salt, nitric acid was at first chiefly used; but in consequence of its relatively high price, sulphuric, muriatic, or acetic acid has been frequently substituted upon the great scale.

There is another application of chrome which merits some notice here; that of its green oxide to dyeing and painting on porcelain. This oxide may be prepared by decomposing, with heat, the chromate of mercury, a salt made by adding to nitrate of protoxide of mercury, chromate of potash, in equivalent proportions. This chromate has a fine cinnabar red, when pure; and, at a dull red heat, parts with a portion of its oxygen and is mercurial oxide. From M. Dulong's experiments it would appear, that the purest chromate of mercury is not the best adapted for preparing the oxide of chrome to be used in porcelain painting. He thinks it ought to contain a little oxide of manganese and chromate of potash, to afford a green color of a fine tint, especially for pieces that are to receive a powerful heat. Pure oxide of chrome preserves its color well enough in a muffle furnace; but, under a stronger fire, it takes a dead-leaf color.

The green oxyde of chrome has come so extensively into use as an enamel color for porcelain, that a fuller account of the best modes of manufacturing it must prove acceptable to many of my readers.

That oxide, in combination with water, called the hydrate, may be economically prepared by boiling chromate of potash, dissolved in water, with half its weight of flowers of sulphur, till the resulting green precipitate ceases to increase, which may be easily ascertained by filtering a little of the mixture. The addition of some potash accelerates the operation. This consists in combining the sulphur with the oxygen of the chrome acid, so as to form sulphuric acid, which unites with the potash of chromate into sulphate of potash, while the chrome oxide becomes a hydrate. An extra quantity of potash facilitates the deoxidizement of the chromic acid by the formation of hyposulphite and sulphuret of potash, both of which have a strong attraction for oxygen. For this purpose the clear lixivium of the chromate of potash is sufficiently pure, though it should hold some alumina and silica in solution, as it generally does. The hydrate may be freed from particles of sulphuric acid upon it, which dissolves; after which it may be precipitated, in the state of a carbonate, by carbonate of potash, not added in excess.

By calcining a mixture of bichromate of potash and sulphur in a crucible, chromic acid is also decomposed, and a hydrated oxide may be obtained; the sulphur being partly converted into sulphuret of potassium, and partly into sulphuric acid (at the expense of the chromic), which combines with the rest of the potash into a sulphate. By careful lixiviation, these two new compounds may be washed away, and the chrome green may be freed from the remaining sulphur, by a slight heat.

Liebig and Wöhler have lately contrived a process for producing a subchromate of lead of a beautiful vermilion hue. Into saltpetre, brought to fusion in a crucible at a gentle heat, pure chrome yellow is to be thrown by small portions at a time. A strong ebullition takes place at each addition, and the mass becomes black, and continues so while it is hot. The chrome yellow is to be added till little of the saltpetre remains undecomposed, care being taken not to overheat the crucible, lest the color of the mixture should become brown. Having allowed it to settle for a few minutes, during which the dense basic salt falls to the bottom, the fluid part, consisting of chromate of potash and saltpetre, is to be poured off, and it can be employed again in preparing chrome yellow. The mass remaining in the crucible is to be washed with water, and the chrome red being separated from the other matters, is to be dried after proper edulcoration. It is essential for tne beauty of the color that the saline solution should not stand long over the red powder, because the color is thus apt to become a dull orange hue. The fine crystalline powder subsides so quickly to the bottom after every ablution, that the above precaution may be easily observed.

As *Chromic Acid* will probably ere long become an object of interest to the calico printer, I shall describe here the best method of preparing it. To 100 parts of yellow chromate of potash, add 136 of nitrate of barytes, each in solution. A precipitate of the yellow chromate of barytes falls, which being washed and dried would amount to 130 parts. But while still moist, it is to be dissolved in water by the intervention of nitric acid, and then decomposed by the addition of the requisite quantity of sulphuric acid, whereby the barytes is separated, and the chromic acid remains associated with the nitric acid, from which it can be freed by evaporation to dryness. On re-dissolving the chromic acid residuum in water, filtering and evaporating to a proper degree, 50 parts of chromic acid may be obtained in crystals.

This acid may also be obtained from chromate of lime, formed by mixing chromate of potash and muriate of lime; washing the insoluble chromate of lime which precipitates, and decomposing it by the equivalent quantity of oxalic acid, or for ordinary purposes even sulphuric acid may be employed.

Chromic acid is obtained in quadrangular crystals, of a deep red color; it has a very acrid and styptic taste. It reddens powerfully litmus paper. It is deliquescent in the air. When heated to redness it emits oxygen, and passes into deutoxide. When a little of it is fused along with vitreous borax, the compound assumes an emerald green color.

As chromic acid parts with its last dose of oxygen very easily, it is capable in certain styles of calico printing of becoming a valuable substitute for chlorine, where this more powerful substance would not from peculiar circumstances be admissible. For this ingenious application, the arts are indebted to that truly scientific manufacturer, M. Daniel Kœchlin, of Mülhouse. He discovered that whenever chromate of potash has its acid set free by its being mixed with tartaric or oxalic acid, or a neutral vegetable substance, (starch or sugar for example,) and a mineral acid, and a very lively action is produced, with disengagement of heat, and of several gases. The result of this decomposition is the active reagent, chromic acid, possessing valuable properties to the printer. Watery solutions of chromate of potash and tartaric acid being mixed, an effervescence is produced which has the power of destroying vegetable colors. But this power lasts no longer than the efferescence. The mineral acids react upon the chromate of potash only when vegetable coloring matter, gum, starch, or a vegetable acid are present, to determine the disengagement of gas. During this curious change carbonic acid is evolved; and when it takes place in a retort, there is condensed in the receiver a colorless liquid, slightly acid, exhaling somewhat the smell of vinegar, and containing a little empyreumatic oil. This liquid heated with the nitrates of mercury or silver reduces these metals. On these principles M. Kœchlin discharged indigo blue by passing the cloth through a solution of chromate of potash, and printing nitric acid thickened with gum upon certain spots. It is probable that the employment of chromic acid would supercede the necessity of having recourse in many cases to the more corrosive chlorine.

The following directions have been given for the preparation of a *blue oxyde* of chrome. The concentrated alkaline solution of chromate of potash is to be saturated with weak sulphuric acid, and then to every 8 lbs. is to be added 1 lb. of common salt, and half a lb. of concentrated sulphuric acid; the liquid will now acquire a green color. To be certain that the yellow color is totally destroyed, a small quantity of the liquor is to have potash added to it, and filtered; if the fluid is still yellow, a fresh portion of salt and sulphuric acid is to be added; the fluid is then to be evaporated to dryness, redissolved, and filtered; the oxide of chrome is finally to be precipitated by caustic potash. It will be of greenish-blue color, and being washed, must be collected upon a filter."

OCHRES.

Since the numerous beds of brown iron ore in western Vermont are more or less abundantly enveloped in ochre, deposits of this substance frequently raise expectations of the discovery of ore. The probability of such discovery, since ochres accumulate from other causes, must be judged of in each case. In some cases ochre accumulates in depressions by the wash of adjacent lands which contain more or less of disseminated particles of iron. We have also found one or two cases of greenstone, in dykes, containing so much iron as by decomposition to afford a hard ochreous clay, in which the feldspathic grains are visible in a fresh fracture. An interesting example of this kind was pointed out to me by His Honor Lieutenant Gov. Eaton in Enosburgh, about one and a half miles south-south-east from the centre of the town. A singular rock in the west part of Mendon, not sufficiently exposed for examination in place, may be such a greenstone undecomposed, as it contains a large per centage of brown iron ore.

MANGANESE.

Brandon. A specimen of *psilomelane*, with implanted crystals of an ore of manganese, from Mr. Conant's ore bed, has been analysed by Mr. Olmsted with the following results:

Red oxide of manganese,	81.38
Oxygen,	2.74
Magnesia,	2.22
Silica,	3.60
Water,	9.75
	99.69

It contained therefore, if there be no error,

Metallic manganese,	58.755
Oxygen,	25.365

which scarcely differs from the constitution of sesqui-oxide of manganese.

Plymouth. We have before mentioned that the ores of manganese occur with the brown iron ore near the furnace. It is not improbable that workable manganese may be found in this vicinity.

COVENTY. A locality of *manganese spar* occurs in this town, two miles south-west from the village; and two large boulders, perhaps derived from this locality, have been found by Mr. Hall in Albany. This mineral is of no use except as an ornamental stone. It receives a good polish, and is used for inlaid work.

COPPER.

CORINTH. A rich vein of copper pyrites, occurs in this town, two and a half miles west of the village. Not improbably it is a part of the great vein of pyrites which is worked in Strafford. The vein is here twenty feet wide, and the copper pyrites is mostly in a portion eighteen inches wide. A specimen has been analized by Mr. Olmsted, with the following results:

Copper,	27.28
Iron,	37.91
Sulphur,	33.70
Silica and mica,	1.11
	100.00

The ore appears to be rich, and is worthy of attention.

LEAD AND SILVER.

CHITTENDEN. "The lead mine" was examined in company with Your Excellency and with Dr. Ewing of Pittsford, and much admiration was elicited at the perseverence of those who had been concerned in the works. A vein of white quartz, near the summit of a high mountain, had been quarried to the open air, and at some distance below a drift had been run ten rods into the solid rock to meet it. Some small portions of *galena* were found, and specks of the ore may now be seen in the white quartz.

A specimen of this ore was analyzed by Mr. Olmsted, without detecting any silver, which, from the analogy of the New Hampshire ores in metamorphic rocks, we had expected analysis would discover. For particulars of the process, the report of Mr. O. may be consulted.

THETFORD. One hundred rods north-east of Thetford Hill is "the mine" of *galena* and *blende*, where an excavation has been made to the open air sufficiently to reveal the character of the vein, which dips about 20° to the south-east, the slate in which it occurs having a dip of 40° to the east 30° south. The vein

is mostly from one to four inches wide, but irregular and more or less mixed with other minerals. It is not likely to be of any further use than to afford cabinet specimens of galena and blende, and the owner of the land, we are informed, asks $0.00 for the privilege of mining ad libitum, although the vein is worth many fold more than that of Chittenden.

Mr. Olmsted's analysis of this ore in the moist way afforded traces of *silver*, and Dr. Thayer informed me that cupellation of a considerable quantity by another person had yielded a button of that metal.

The geological position of lead ore appears to be in the palaeozoic rocks. The ore of New York, and the vast quantities which exist in the western States are in these rocks: and in his able report of exploration in the great lead region of Iowa, &c. made by order of the Secretary of the Treasury of the United States, Mr. D. D. Owen has shown that the formations containing the lead ore are the equivalents of those which, in the north of England and in Scotland, have been considered the richest lead country in the world. But if, as is not impossible, many of the so-called primary rocks of Vermont are metamorphic palaeozoic rocks, may we not then hope to find workable veins of lead in these rocks? Mr. Owen has given us an answer to this inquiry:

> "It behooves us to remember that the metalliferous capacity of rocks depends rather upon their lithological character than upon their precise age. Phillips, in a recent geological treatise justly remarks: "It is not because of any peculiar chemical quality that limestone yields most lead ore on Aldstone Moor, but because it is a rock *that has retained openness of fissure*. Gritstones, in many mining fields near Aldstone Moor, are equally productive; but shales * * have closed up their fissures, and their crumbling faces appear to have rejected the crystallizations, which have attached to the harder limestone, grindstone, and chert."

In this connection we cannot forbear mentioning the remark made to us by a practical miner, who was expressing his belief that there was no workable ore in the Chittenden mine,—'that the rock there was so hard that the lead could not grow in it.' As is often the case with practical men, the fact was correct, although the theory of growth was such as we cannot subscribe to. The English geologist quoted by Mr. Owen has exactly expressed the idea of the miner so far as relates to the fact. But Mr. Owen further remarks:

> "All other things being equal, the older the rock, or, in other words, the nearer it approaches the inferior igneous rocks, (the presumed sources of metallic ores), the greater is the probability of its being rich in metals."

And if so, should not metamorphic rocks, being so much nearer the sources of igneous agency than the palaeozoic rocks, contain greater quanties of lead? The usual fact that they do not is not inconsistent with the general theory stated by Mr. Owen, for as the ores of zinc and lead are quite easily volatilised, they may have been sublimated out of those rocks which have been subjected to powerful metamorphic agency, while others less intensely heated have received and retained them. If extensive veins and deposits of lead once existed in Vermont, we should therefore expect now to find only some small vestiges remaining. In this view of the subject, we see the ground of the remark before quoted, that

"The metalliferous capacity of rocks depends rather upon their lithological character than upon their precise age."

Nevertheless it must be admitted that some valuable lead mines exist in metamorphic and even in igneous rocks, where perhaps the igneous agency was not continued so long as in other cases, or where other circumstances may have prevented the escape of this ore. It is therefore not probable but possible that galena exists in the State in workable quantity.

ANTHRACITE COAL.

NORWICH. We mentioned last year, giving the authority of Dr. Davis, that a small quantity had been obtained in thin layers. Since then we have received the following statement from a gentlemen, whose name, if we considered ourselves at liberty to give it, would be regarded as ample guarantee for what he actually states.

"About eight or nine years since, I heard the rumor of anthracite having been found in Norwich, Vt., and in company with Prof. ——, visited the farm and 'locality,' where it was said to have been discovered. The rock is bright mica slate; on the general declivity of the hill, a few miles back from the Connecticut river; the locality right *at* the surface—with enough of digging to shew some fresh fractures of the rock—but we found there nothing that bore any resemblance to anthracite. On our return to the farm house, we were shown specimens of genuine Pennsylvania anthracite in a box. There can be no doubt whatever, that the whole matter is a gross deception, and we learned then, there was a close connection between the discovery of the coal and a desire to sell the farm, preparatory to a removal west."

On the other hand, however, we have received the following account from Dr. Davis.

"The statement I gave you, was from *my own personal* examination, at two or three different visits to the location, and I can say decidedly, that the specimens which I dug from the rock could not have been placed there by human agency, unless there is some more subtle and mysterious slight of hand than has hitherto been exhibited to the public. Every appearance indicated to me, that the fragments of coal were forced into crevices by subterranean combustion, and they had evidently occupied the position in which they were found for a series of years.

"Mr. Smith, who was owner of the place at the time, and who made the discovery, was a member of the congregational church, and a very candid and respectable man, altogether above any suspicion of intrigue or speculation, and at the time, had no anxiety to sell his farm, but actually leased this location to an agent of the copper company, for a term of years to be wrought upon shares, and afterwards sold the place to another person at a moderate price previous to the expiration of the lease."

Whether we have cleared up the subject by introducing these communications may admit of some question.

POULTNEY. We have been informed that exploration for coal has been going on during a part of the present year in a black slate, and that the desire has been expressed that we should visit and examine the locality, which we will certainly do, as soon as the coal shall have been discovered.

GRAPHITE.

BARNET. Mr. Maclaren shewed me specimens obtained by himself in this town, mixed with some argillaceous foreign materials, which may not prevent its being of considerable value for many purposes.

MATERIALS FOR POTTERY AND PORCELAIN.

In the last report we designated the white clays, which exist abundantly as associated with the taconic rocks, as *kaolin*, using this term simply in reference to its mineral character without regard to the origin. Since, however, the theory of the origin of *all* kaolin in granites which consist mostly of feldspar generally prevails, this term is liable to convey an idea, which is erroneous in reference to the white clays referred to. We shall, therefore, adopt the suggestion of President Hitchcock, in his letter which will be appended, and use the term pipe clay or white clay.

MONKTON. Further inquiries have confirmed my doubts of the correctness of the writer referred to last year, who ascribed the origin of the pipe clay in this town to the decomposition of graphic granite. The associations of this clay are similar to those of the other stratified deposits of the taconic range. The excavations which will be made by the present owners, the Messrs. Farrar's, will, however, decide the question. The following letter from the Messrs. F.'s show that this bed is likely to be made avaliable, and we may hope that their experience in common pottery will ensure them success in the enterprise, which is one of much importance to their vicinity.

VERGENNES, Sept. 28, 1846.

"*Dear Sir*:—
In accordance with your request, I send you a statement of our fire brick works at this place.

We use principally the Monkton kaolin. With this we mix a portion of New Jersey clay, known as the alum clay; which is extensively used and sustains a high reputation for the manufacture of fire brick. We also combine with these a portion of burnt brick suitably crushed, and to exclude every thing but the best materials for sustaining heat, we procure the well known sandstone from Willsborough, N. Y., which we reduce by water-power to the proper fineness, to give the right texture to our brick. This has been proved by experiment not inferior to fire clay for resisting the effects of heat.

These articles are well ground in a mill, and the brick made of them are allowed to harden slightly, and are then pressed to render them solid and their surface and edges regular, and to complete the process they are burned in a kiln constructed for the purpose.

We have got our works but recently into operation and burned the first kiln of brick, and intend to continue the manufacture of them constantly. As to the extent of our business, I will only add, we have incurred expense, and bestowed labor and time thus far, in the belief that the advantage of possessing the right materials, and our location in the centre of an extensive region, abounding in the manufacture of iron and other articles for which these bricks are essential, will at a future time enable us to speak of no inconsiderable amount.

Very respectfully yours,

E. L. & E. H. FARRAR.

Prof. C. B. Adams, Middlebury College.

Bennington. A specimen of the pipe clay used by Messrs. Norton and Fenton, has been analysed by Mr. Olmsted, and found to contain

Silica,	18.20
Alumina,	65.60
Magnesia,	3.24
Water,	13.20
	100.24

The great amount of alumina may excite some surprise, and as the ultimate analysis alone is likely to convey an incorrect idea of the constitution of this clay, I introduce here extracts from letters of Mr. Olmsted, referring to a trial which had been made in Boston of the Monkton pipe clay, as a material for the preparation of the mordant, acetate of alumina, for dyeing.

"With regard to the *kaolin*, it is probable to me that Mr. ——— simply treated the specimen from Monkton with acid and precipitated the alumina from the solution. By this means we should obtain simply any free alumina present while the silicate of alumina would gelatinize without decomposing. The specimen I analysed was fused with carbonate of potassa in a platinum crucible, and the fused mass treated with water:—the residue undissolved by water treated with hydrochloric acid, complete and easy solution effected, and the alumina precipitated from the acid solution, the silica being thrown down from the aqueous solution. The residue left on treating the fused mass with water very evidently contained besides the alumina separated from the silica another portion, which had the appearance of alumina that had simply undergone intense heat in an uncombined condition. I am not sufficiently acquainted with the art of pottery to know, but suppose the silicate of alumina to have no virtue of its own, the uncombined alumina and silica being alone serviceable."

"I made some examination of the kaolin with regard to the amount of free alumina present, but I think the experiments of the manufacturer are the only safe guide. The amount of free alumina that I could separate by acid, was only about thirteen per cent."

It appears therefore that the failure of the attempt to introduce this article into use for the purpose above named is due, if, as is probable, the constitution of the Monkton clay is similar to that of Bennington, not to the want of alumina but to the condition in which it exists in the clay. Mr. Olmsted's illness prevented him from pursuing this subject, and determining how much alumina exists in each of the three states indicated, viz. free, allotropic by heat, and combined with silica. If we allow the thirteen per cent. for the free alumina, there will remain 52.60 in the other forms. Of this, all the silica present in the clay is capable of combining, even as a protosilicate, with only about 20.12 of the alumina, leaving 32.48, nearly one-half, in an allotropic state. But as it is by no means to be supposed that all the silica is combined with alumina, it would seem that a larger portion of the latter has been altered by heat; and the fact of this condition of a considerable portion of the alumina may be considered as confirmatory of the theory that this clay is a member of a metamorphic stratified rock. The economical results are of no small importance, and we hope to be able hereafter to present something more definite on the proportion of the alumina in these several states.

Pownal. Prof. Dewey informs me that there is a bed of the white clay in this town.

Cabot. At the southwest corner of Joe's pond, by the sides of a road running west from the pond, are numerous large ligniform masses of albite, with a bladed structure, and the ledge from which it was derived may probably be discovered without much difficulty. It may be of use in the composition of a paste for porcelain, and if nearer to Bennington might be of value in some of the various kinds of pottery manufactured there. On account of the structure of these masses, they may be split by a blow with the edge of the hammer in the manner in which wood is split with an axe, but with greater facility, into very long and slender pieces.

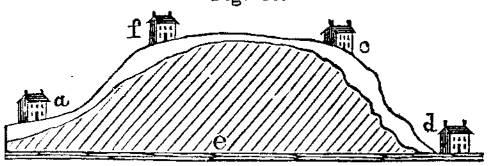
ARCHITECTURE.

"Geology sustains important relations to architecture, first in the selection of builing sites, and, secoud, in the choice of stones or of materials for the manufacture of bricks."—*Ansted.*

In the selection of a building site, reference must be had not only to the facilities of drainage of the surface, but also to the structure of the earth beneath the surface. The almost universal covering of drift in this State, together with the inequalities of surface, render artificial drainage either unnecessary or very easy; the pleistocene sands are still more porous, and a great portion of the pleistocene clays are rather thinly spread over drift, and are therefore easily penetrated and drained. In the latter case the geologist can often judge before trial of the relative thickness of the clay in different situations. In general it will be found to increase in thickness, as we descend the numerous hills whose summits of drift appear above the general level of the clay.

In choosing a situation on the brow or at the base of a hill, reference should be had to the geological structure of the hill. If, as in figure 44, we have a hill of highly inclined strata covered

Fig. 44.



with the loose materials of drift, the houses *a* and *f* will obviously be in danger from slides, and this danger will be the greater if the rock is covered with clay. If the side of the hill, *c d*, has a slope to any point of the compass between north and south-west, it is probable that the surface of rock beneath the outer covering is smooth, and there is therefore danger of slides. If, however, the slope is to the east, as is supposed in the figure, the surface of the rock may be uneven, and there is less danger of slides. A situation at the southern extremity of such a hill, as at *e*, like that of the Capitol of this State, will always be secure.

Some situations near the margins of rivers on the pleistocene clays are exposed to the danger, which arises from the washing away of loose drift materials beneath a superincumbent mass of clay, when at length a slide suddenly takes place towards the river. In this way a house was destroyed in Weybridge a few years since, and the inmates narrowly escaped. The localities of such slides are ever after marked by a very broken undulating surface, which remains as a warning for the future.

The materials which are used in the various arts of construction are occasionally put to other uses, and to avoid repetition of the same subject we shall under this head introduce all that we have to say now respecting such materials.

BUILDING STONES.

Further examination of the line of granite eruptions, which we have mentioned as existing from Lake Memphremagog to Dummerston with interruptions, has convinced us of its great value as a building material. Although there are various degrees of coarseness, most of these immense masses are well adapted in their degree of fineness, as well as in their general freedom from

iron stains, for the noble and substantial kinds of architecture, which wealth may at no distant period demand. In those parts of this range where the granite does not appear, gneiss, thick bedded and of good quality for building purposes, takes its place to a considerable extent. Thus a range of gneiss extends from Townshend to Chester inclusive. In the want of an immediate demand for good quarries we may defer to a future occasion the details of the subject.

A peculiar variety of binary granite, composed mostly of feldspar, with a small portion of quartz, is associated with the argillaceous slate of the Connecticut river valley, and is seen in Guilford and the north-east corner of Thetford. Although so distinct from all the other varieties, hand specimens from these distant localities cannot be distinguished. In Thetford it occurs with natural joints, which have a very smooth surface, and will both greatly facilitate the quarrying and increase the value of the stone.

MARBLE.

Plymouth. The quarry of beautiful variegated brecciated marble in this town is not worked at present on account of the expense of transportation. The opening of a rail-road within six miles will remove this obstacle, as well as give increased activity to the iron works of this town.

Sudbury. The quarry of Mr. John Hall near the north part of this town is remarkable for the regular jointed structure and joint-like divisions of the thin beds of marble, which to a considerable extent, supercede the necessity of sawing. This marble is of a light greyish blue color, and is much used for grave-stones. The beds have a direction of north 40° east, and a dip of 10° south-east, and the principal set of joints, which comprises both the greatest number and those which cleave with the greatest facility, has a direction of north 45° west. Cabinet specimens, illustrative of jointed structure, may be obtained twenty to twenty-four inches long and only one to two inches in the transverse dimensions. The beds are more commonly from one-half to three inches thick.

On the middle of the west line of this town, are the newly opened quarries of Mr. Manley, in which are both thin and thick beds of white marble with a very finely granular almost compact texture. A few of the beds are red and others green, and of these a part are schistose with a nodular or imperfect concretionary structure, but these useless layers form only a small part of the ledges. It would be difficult to produce a white marble from any part of the world which should surpass this in beauty. In the more southerly of these quarries the beds have a direction of north 5° east, and a dip of 24° east. A short distance north of this quarry, is a small insulated hill in which is the other quarry with the beds dipping 10° to the south-west, of a pure white, greyish blue, and a delicate flesh color.

RUTLAND. *Hyde's quarry.* Two specimens from this quarry have been analysed by Mr. Olmsted, one of a pure white granular variety and the other with a greenish tinge and rather less friable.

	Greenish variety.	White variety.
Carbonate of lime,	85.45	97.73
Alumina and iron,	——	.59
Silica and mica,	14.55	1.68
	100.00	100.00

We had confidently supposed this to be a magnesian limestone, and the result has not a little surprised us as it did the analyst, who suggests that the friableness of this marble may be due to the intermixture of grains of the silica, which in the greenish variety appears to be abundant. The fineness of these grains and the uniformity of their diffusion probably prevents any difficulty arising from it to the manufacturer of the marble. The purer variety, however, is more abundant in the quarry.

In the greenish variety was the additional reason for anticipating the presence of magnesia, that it was probably colored with the same green non-elastic lamellar mineral, whose external characters were obviously those of talc. Whether this is a green mica requires further examination.

BRANDON. A specimen of the fine white statuary marble has been analysed by Mr. Olmsted, as follows:

Carbonate of lime,	99.51
" " magnesia,	trace.
Silica and other insoluble matter,	.29
Water and loss,	.20
	100.00

The constitution corresponds well in purity with the spotlessness of the appearance of this elegant marble. The external characters of this marble also led to the supposition that it was dolomitic.

MIDDLEBURY. *Gibbs' quarry* in the north part of the town furnishes white marble of a fine texture, which is for the most part thick bedded; but the beds are uneven and traversed with irregular seams, which injure the quarry for marble. It is celebrated for furnishing excellent lime. The mineralogist will find here a thin stratum of the brilliant semi-crystalline brown spar variety of dolomite.

The quarry of *Slason and Ormsbee,* not far from the geographical centre of the town, resembles that last mentioned. The marble is of very fine texture, and mostly white, but the beds are more or less unequal and irregular, and some talciferous strata, with the adjacent beds, are much contorted. The general direction is north 10° west, and the dip in the average 75° east; some planes of division in a part of the quarry which closely resemble planes of deposit have a dip of 20° east.

Phelps' quarry, near the northwest corner of the town, is very similar to Manley's quarry in Sudbury, not only in the quality of the marble, but in containing the same jaspery red and green talciferous schistose subconcretionary strata; and since also the direction of the strata and of a line uniting the two quarries coincide, it would seem to be a necessary inference that the two quarries are in strata which were originally continuous; yet the continuity of this line is now interrupted by the northern and narrow extremity of the Taconic slate. On the west side of this slate the limestone, including the Sudbury quarries, has been called sparry limestone, and this Stockbridge limestone on the east side has been regarded by some as another formation. It would seem to be an unavoidable inference from this and some other facts that these limestones were once continuous, but that their continuity was broken by the upheaval of the originally subjacent and now intervening Taconic mountains, and accordingly where these mountains in Brandon and Sudbury suddenly terminate in low hills, we find the intervening slate contracted in a corresponding degree, and terminating like a wedge a few miles farther north in Cornwall; to the north of which, in the absence of a geographical division, we have not been able to continue the boundary line. In making this suggestion, for it is merely a suggestion, we do not intend to deny that these limestones before they become metamorphic may not have comprised more than one formation, but to suggest a doubt whether the geographical division is a geological division.

To recur to the point from which we have digressed; the ridge in Middlebury, at the north extremity of which is Phelps' quarry, extends for nearly a mile to the south, and in most of the distance is capable of furnishing excellent marble from this inexhaustible source.

ISLE LA MOTTE; *Hill's quarry:* and SWANTON. A specimen of black marble from the former, and one of the dove colored marble from the latter place have been analysed by Mr. Olmstead, with the following results:

	Black.	Dove colored.
Carbonate of lime,	87.94	94.66
" " magnesia,	4.56	.23
Alumina and iron,	2.60	1.09
Insoluble matter, mostly silica,	4.80	2.39
Water and loss,	.10	1.63
Protoxide of manganese,	trace	——
	100.00	100.00

SERPENTINE.

In Dr. Feuchtwanger's Treatise on Gems, we find the following important suggestions on the uses of this rock.

"It is easily wrought on lathes into various articles; such as snuff-boxes, vases, ink-stands, &c. In a small place at Zoblitz, in Saxony, several hundred persons are constantly employed in the manufacture of boxes, trinkets, and chimney-pieces. The locality in Grenada, in Spain, has supplied many churches and palaces of Madrid with large columns, and other ornaments. It is really surprising that the inhabitants of those districts where the precious serpentine is found, have not yet employed it as an article of trade, as the quality of the American serpentine is, if not superior to the English and Spanish, certainly not inferior to any hitherto found; and I trust that the day is not far distant when our parlors will be embellished with mantle-pieces, tables, and mantle ornaments, made of it. Candlesticks, mugs, pitchers, knife-handles, firearm-stands, jamb-hooks, and many other domestic articles, instead of silver-plated, steel, and cast-iron ware, might be formed of it and used."

The objection which exists against the introduction of this article as a substitute for marble, being founded chiefly on the extreme difficulty of obtaining, especially of the more beautiful varieties, sufficiently large pieces free from seams, does not apply to the numerous small ornamental articles, which may be manufactured from it.

Cavendish. On visiting the shop where the beautiful serpentine, formerly belonging to Mr. Proctor, had been worked, we were much impressed with the number and beauty of the varieties of color, which were revealed on the smooth surface of the sawed slabs. With the variety of color in a given piece, however, appears to be a corresponding inequality of structure, which renders the slab more liable to fracture. This may account for what, so far as we have seen this rock, appears to be generally true, that the most elegant varieties are most invariably prone to fracture under the hammer into the most irregular fragments, so as to bid defiance to the rules we had adopted respecting the size and form of our specimens. The difficulty may be partly met by giving a greater thickness to the slabs, and avoided by using the stone for purposes which will not expose it to fracture, and for small articles.

Roxbury. We had anticipated an advantageous exhibition of the ledge described last year by the rail-road excavation, but find that this had been made chiefly on the east side, where the serpentine is more abundantly traversed by seams. A beautiful polished slab in a table in the congregational meeting house in West Randolph was obtained from this locality.

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 one-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 constitutes 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 specimens of 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.

The general distribution of water power in this town may be readily conceived by a glance on the map at the head waters of the Missisco, which converge from a variety of directions into the basin, in which the village is situated, and which opens to the north for the channel of this river. Accordingly the serpentine will require but very little transportation to water power sufficient for sawing, and in fact, most of it is within a few rods of the main channel of the Missisco.

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 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.

Jay. We have before, under the head of chromic iron, described a locality of serpentine in this town, where there is an extensive ledge within a few rods of good water power.

SOAPSTONE.

Beds of soapstone occur in Grafton, Cavendish, Bridgewater, Bethel, Rochester, Braintree, Moretown, Waterbury, Stow, Sterling, Johnson, Eden, Lowell, Westfield, Troy, Richford, Enosburg, Belvidere, and Waterville. Some of these localities were described last year.

The very common association of serpentine and soapstone, is worthy of notice, as of both economical and scientific interest. Thus, in Cavendish, the soapstone lies on the west side of the serpentine, with a few rods of mica slate intervening; in Rochester, it is closely associated with serpentine; in Lowell, it is on the east side of the east ledge, and on the west side of the west ledge; in Westfield, on the west side, and in North Troy, on the west side of the serpentine. Steatite appears generally to occur in beds rather than in prolonged strata, and these beds are usually of great thickness as compared with their length.

Cavendish. The mica slate, which intervenes between the serpentine on the east, and the soapstone on the west, occupies a space of about ten rods wide on the main road from Ludlow to Proctorsville. The soapstone is several rods wide, and the quantity is inexhaustible. Much of it is undoubtedly of excellent quality, and being on the route of the Rutland rail-road, is worthy of careful exploration.

Bethel. In West Bethel, on the Rochester road, is a bed which has been examined by my assistants, who report it to be forty feet wide. Also, in the north part of Bethel, near the actinolite locality before mentioned, is a bed of laminated talc, most of which is sufficiently compact to be quarried as steatite.

Rochester. Messrs. Hall and Thompson, report the bed in this town to be at least forty feet wide.

Braintree. Dr. S. W. Thayer, Jr., informs me that there is a bed in this town, in a line with that of Bethel, and with the serpentine of Roxbury and Northfield.

Moretown. Associated with serpentine in the north-west corner of the town, is a bed of laminated talc, which can be wrought as soapstone. It occurs not far south of the Winooski, near the road, where a common stone wall has been built mostly of fragments of talc.

The beds in Waterbury, Johnson, and Eden, have been examined but not yet described by my assistants.

Lowell. About a mile east of the village, on land of Mr. Pearl C. Brigham, is a bed of soapstone which has not yet been quarried. The portions near the surface which we saw, are so closely filled with crystals of brown spar as to be of no value, but this is not likely to be true of the entire bed. Mr. Hall reports a bed west of the west ledge of serpentine, as being "dark colored and hard." We were also shewn a piece of excellent quality in the possession of an individual, who wished us to pay him for the privilege of examining the bed.

WESTFIELD. At the locality of the serpentine before mentioned, steatite, of many varieties and of excellent quality, occurs in junction with the west side of the serpentine at the road side. Some of this soap-stone is of a very beautiful dark green; some portions are cream colored mottled with darker colors, and some of a light greyish blue, very soft and free.

TROY. Messrs. Hall and Thompson report that the bed in Sonth Troy, "one-half mile east of the meeting house, is too hard to be wrought, and is filled with crystals of octahedral and sulphuret of iron." We have before mentioned the junction of serpentine and soapstone in North Troy. The latter is abundant, with light horn colored and greyish blue varieties, and of good quality.

ENOSBURGH. In the east part of this town a bed has been recently discovered.

Messrs. Hall and Thompson report a bed in BELVIDERE, and in their report of last year describe the bed of WATERVILLE.

THETFORD. 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.

In the regions which we have examined, the valley of the Missisco east of the Green Mountains contains the greatest abundance of this valuable stone, as well as of its associate serpentine, although neither have yet been quarried to any considerable extent. The day is probably not very far distant, when the construction of the Passumpsic rail-road through the valley of Lake Memphremagog, and perhaps of a branch to some part of this upper valley of the Missisco, will render these resources more available.

ROOFING AND WRITING SLATES.

THETFORD. In the northeast corner of this town is a range of argillaceous slate, which is extremely fissile and soft, and, without any tools, is easily peeled off from the side of the ledge in large sheets. The lamination has a direction of north 10° east. It is of easy access on the east side from the main road

near the Connecticut river. The softness of this slate has been objected to, but this would only require a little more care in handliug it, for the durability must depend more on the chemical constitution. We have before remarked that the fine drift scratches have been preserved on the soft slates in Fairhaven through untold ages. Probably if this ledge were opened, it would be found less fissile. Mr. Bartholemew, the owner of the ledge, has used this roofing slate for many years with success.

ALBANY. A narrow range of argillaceous slate extends from the southern extremity of Lake Memphremagog to Montpelier between the calcareo-mica slate on the east, and the Talcose slate on the west, with an average width not exceeding one mile. In the sontheast corner of Albany, four miles from Craftsbury Common, it occurs in very regular laminae, with a dip nearly perpendicular, and appears to be well adapted in structure for a roofing slate; but at the locality which we examined it is somewhat calciferous, and will not probably be found durable on exposure to rains.

FAIRHAVEN. Nearly two miles north-north-east from the village of Fairhaven is Allen's slate quarry, on the west side of a hill at the base of which appears the sparry limestone. The laminae of the slate have a direction of north 40° east, and dip of 10° south-east; but the dip is variable in consequence of gentle undulations of the laminae. These undulations, however, are not abrupt enough to diminish materially the value of the quarry, while natural joints, some with a direction of north 30° west, and others that of an east and west direction, facilitate the removal of the slate. The slates of this quarry are soft and free from grit, and answer for writing as well as for roofing slates. Indeed they are quarried chiefly for the former purpose, for which they are well adapted.

STONE POSTS.

These are made not only of granite in the granitic region of Orange county, but of mica slate in the west part of this county. They are obtained with great facility, of a fine dark blue variety, in consequence of the intersection of strata from three to five inches thick by natural joints, which are a few inches distant and at right angles to the plane of stratification. In RANDOLPH, between the west and centre villages, such posts are quarried, and sold at 5 to 20 cents each.

LIMESTONE.

Mica slate limestone. The limits of the calcareo-mica slate formation have now been pretty accurately determined, and we have before mentioned the interesting and important fact that the marl beds east of the Green Mountains are found only on this formation and the argillaceous slates. The boundary between these formations, as laid down on a geological map, extending from Canada to Massachusetts, is therefore of much economical importance.

Although all the beds, which are abundantly interstratified with the mica slate, are siliceous, some of them contain much more lime than others. In general, they are the richest and most abundant in the middle of the eastern half of the State. The following are the results of some analyses by Mr. Olmsted.

	Craftsbury.	Hardwick.	Danville.	Barnet.	Vershire.
Carbonate of lime,	30.82	52.47	53.50	47.07	36.78
" " magnesia,	2.51	3.72	2.20	4.00	3.27
Alumina and Iron,	2.05	3.00	1.90	1.70	8.80
Insoluble matter, mostly silica,	60.00	39.90	38.90	44.70	50.15
Water and loss,	4.62	.91	3.50	2.53	1.00
Protoxide of manganese,	——	——	——	trace	——
	100.00	100.00	100.00	100.00	100.00

In Tunbridge, Mr. Osmer P. Farnham has burned this limestone, and has used it with good results, both on land and for mortar.

In Cavendish, one-half mile east of Duttonsville, is the limestone quarry of Christopher Webber, Esq. This limestone differs from the common siliceous limestone of the mica slate in several important respects. It is of a dingy white, with thickly disseminated grains of translucent quartz, in consequence of which it is quite friable, and is very even bedded, It is included conformably between strata of mica slate, with a direction of north and south, and dip of 30° west. Its thickness is about 25 feet, and it is traceable for three or four miles in the direction of the strike. Large quantities have been burned by Mr. Webber for many years past.

Danville and Vershire are remarkable for the facility with which this limestone disintegrates by atmospheric agency, and although it is therefore unsuitable for a building stone, the benefit to the soil is ample compensation.

A few towns on the Connecticut River are destitute of this siliceous limestone. Such are Thetford and Fairlee.

Talcose Slate Limestone. The white and reddish white granular limestone of Plymouth extends from within a few rods of the north line of the town along a narrow valley to within a short distance of the south line of the town. Great quantities are burned for the supply of the neighboring towns, and there are probably more lime-kilns in this town than in any other five towns

in the State. It is much to be regretted that there are so many rude kilns of rough stone, making a great waste of labor and fuel, instead of one or two large perpetual kilns. Probably there is not now another situation in the State so favorable for an enterprising person, who will erect such a kiln. The reputation of the Plymouth lime is well established, and nothing is wanting but the reduction of price by a more economical process.

Mendon. The bed of white limestone, which was mentioned in the last Report on the authority of another person as occurring in Stockbridge, is mostly in the north-east part of Mendon, and extends, as I was informed, over the Sherburne line. Large quantities of it are burned in the north-east part of Sherburne.

Hancock. We have before mentioned the recent discovery in this town of limestone similar to that of Plymouth, half a mile south of the village, We have not yet visited the locality, but confidently hope that it will be of great value to the vicinity. The limestone appears to be of very good quality.

Bakersfield, In the north-east corner of this town, are beds of white limestone, on land of Mr. Hardy, associated with talcose slate, in interrupted beds. These beds are from six to ten feet thick, with a direction of north 5° east, and a dip of 75° west. Veins of white quartz, which are undoubtedly of igneous origin, cut through the beds of limestone transversely.

Taconic Limestone. Several varieties have been analyzed by Mr. Olmsted; most of which analyses were introduced in connection with the Taconic marble. The following are the results of the analysis of specimens associated with the brown iron ores in North Dorset and in Bristol. It is remarkable that these specimens, and one from the limestone which contains the specular iron in the north-west corner of Milton, and which Professor Emmons regards as the calciferous sandrock of the Champlain rocks, are the only limestones which may properly be called magnesian, among all that were analyzed. They are all without distinct crystalline structure, and are very compact, with a brownish tinge, and argillaceous odor, and are perhaps the last ones in the series of limestones, which would have been suspected of being magnesian. In each case the specimens were taken from immediate proximity to the iron ores.

	N. Dorset.	Bristol.	Milton.
Carbonate of lime,	85.18	51.35	84.45
" " magnesia,	13.11	44.76	12.14
Alumina and iron,	1.79	2.00	1.01
Insoluble matter, mostly silica,	1.49	1.40	1.50
Water and loss,	——	.49	.90
	101.57	100.00	100.00

HYDRAULIC LIME.

On account of the abundance of siliceous and argillaceous limestones over a great part of the State, it may be expected that numerous quarries of stone suitable for the preparation of water cement will eventually be opened, but we have not yet been able to give the subject the attention which it merits. The impure gritty and argillaceous limestones should be sought for this purpose, and subjected to actual experiment. There are quarries in Shoreham, Cornwall, Waltham and Shelburne.

ENGINEERING.

"With regard to this subject there are two points in which the application of geology is both immediate and evident. These are, (1,) The selection of the line along which the road or canal is to be carried, and the management of the cuttings and embankments that may be determined on; and (2,) The selection of the materials for their construction."—*Ansted.*

Many of the principles which determine the selection of a route for a road are of course independent of geological considerations. The latter, however, are always of more or less importance, although in a country over most of which is spread a deep drift deposit, there is little to be said which is not obvious. Many of the principles which apply to the choice of building sites are also applicable in laying out roads. It is also, other things being equal, desirable to locate roads with reference to the materials for their construction, especially since a sparse population can seldom do more than make the roads of the materials on the spot. In Addison county, where the numerous hills of drift above the general level of the clay are much elongated in a north and south direction, the sides of these hills immediately above the clay obviously present the best sites for roads which run north and south; for this elevation is moderate and attended by easy grades, and the materials removed would be such as are needed for a covering for those portions of the road, which necessarily pass over clay. Neither these, however, nor indeed any principles of public convenience have generally determined the location of most of the roads in this part of the State, but they have here, as well as in some other districts, been laid out so as to pass near the houses of individuals, wherever they happened to be. It is not, therefore, surprising that roads thus located, in a region which presents the greatest natural obstacles, so far as materials are concerned, to good roads, should be fairly entitled to the epithet of execrable during the greater portion of the year. Fortunate indeed is it for such roads, that during our long winters nature kindly spreads a mantle over their defects.

In Chittenden county many of the roads, on the other extreme, run over the loose pleistocene sands, and when long dry weather

has at length rendered the clay roads of their neighbors tolerable, travellers and teamsters on these roads are not a little annoyed by the deep sands, which again become tolerable when wet weather has rendered the clay roads nearly impassable. A sandy road, however, is more easily improved than one of clay, requiring a moderate addition of hardpan or clay.

Having had some experience of good and bad roads in Vermont, while travelling in a private conveyance more than 4000 miles during the last two summers in all parts of the State, (except Essex county,) I may be permitted to say that, with the exception perhaps of Addison county, the roads are as good as can be expected from the number of the population. This remark, however, does not apply to the numerous traps, which were originally designed for bridges over small rivulets and sluiceways. Many of the roads in Orange county, especially, not only testify to the natural advantages enjoyed in the materials, but also to the industry with which they have been used. Nevertheless it would be too much to expect, from a resident in Addison county, an assent to the rule which makes the character of the public roads the criterion of the grade of civilization.

In the choice of materials for the improvement of roads, those stones will be found most durable which have great toughness, like most varieties of greenstone, rather than those which are very hard but more brittle. But the absence of greenstone in sufficient quantity will render it necessary to use other materials, such as granite and sandrock, siliceous limestone, mica slate, and argillaceous and argillo-calcareous slates. From the facility with which the latter are broken to a proper degree of fineness, they are more frequently used, and for roads which are not much travelled, better materials do not exist. They are not, however, sufficiently durable for roads that are subject to a great amount of travel.

The comminution of solid rocks for the improvement of roads is, however, in most cases, too expensive a process for a sparse population, and the loose materials of the surface are usually employed. The selection of these must have some reference to the ground on which they are to be used, but ordinarily they will be the following, commencing with the best: 1, rather fine gravel with a tenacity intermediate between loose gravel and hardpan; 2, hardpan; 3, coarse loose gravel; 4, fine do.; 5, sand; 6, loam and sods; 7, clay. With the exception of sand on clay roads, and clay on sandy roads, the last three should never be used when the others are accessible, and perhaps never. Persons from abroad, who have been accustomed to an efficient system of road making, are not a little surprised at the very common use of sods and loam in mending the highway, where gravel of excellent quality for the purpose exists along the road-side, and is exposed in this process of mis-improving roads.

It may not be improper here to make one or two other suggestions on this subject, although they are not geological. It is a matter of complaint in some towns that the expense of bridges comes so heavily upon them, while adjacent towns have little or no expense of the kind. It would seem to be a just principle that those who use the bridge most should pay the most, but in fact, although the town in which a bridge is situated will use it more than any other one town, yet the use of it in the aggregate by those who pay nothing much exceeds that of the one which pays the whole. We apply the remark of course only to the more important routes of travel. The same principle is involved in roads over mountain ridges, which are of greater importance to other towns in the aggregate than to those through which they pass. Thus the road over the mountain between Lincoln and Warren saves five to ten miles in the distance between ten to twenty towns on either side of the Green Mountains, but is rarely used because its bad condition, in addition to the high grades, renders it nearly impassable. Similar cases are very numerous, where the public advantage would far more than equal the expense of bridges and well constructed roads, and hence some of the most important roads in the State are private property. In many of the routes which might be improved or opened to the great accommodation of extensive districts, a county tax would approximate nearly to the principle of assessing the expense where the benefit is derived.

We will take the liberty to make another suggestion: a small expense for guide-boards will save the traveller much perplexity, especially where there are no inhabitants in the vicinity, and the roughness of the country and dense forests render it impossible to foresee the windings of the road, which perhaps bifurcates like the letter Y.

Still more intimate relations exist between railroads or canals and the geological structure of a country, both in respect of their construction and of the natural sources of business. It is unnecessary to offer any suggestions here, since the location and construction of such works are confided in a great measure to persons with whom this knowledge is a part of their profession.

On several miscellaneous subjects, as firestones, whetstones, common and mineral springs, we should have introduced a few facts and suggestions, but the length which this report has reached constrains us to withhold them.

APPENDIX.

A.

Letter from President Hitchcock.

AMHERST, Sept. 1st, 1846.

DEAR SIR—As I have just returned from an excursion of about 400 miles in Vermont, you may expect to receive an account of any geological phenomena, which arrested my attention, especially as I was not accompanied by you. As I travelled rapidly, however, you will not expect that I should go into much detail as to particular localities. I shall merely record a few things which excited interest in my mind, but which may, nevertheless, be of little consequence.

I passed along the eastern part of the State till nearly opposite Montpelier, when I turned northeasterly and crossed the State to Burlington; thence I went southerly on the west side of the Green Mountains to Bennington, whence I crossed the State again to Brattleborough; and truly, although I had crossed the Green and Hoosac Mountaintains in a great many places, I never met with so fine a section as that laid open along the Winooski (Onion) river. The strata west of Montpelier stand nearly perpendicular, and are more continuous and regular in that dip than on any other section across them that I have seen. And what an enormous thickness of talcose slate, especially is there exhibited. For that formation extends most of the distance from Montpelier to Burlington; except that perhaps there may be a central band of mica slate, or gneiss, in the highest part of the Green Mountain range. This formation can hardly be less than twenty miles thick! Now admitting that the strata are folded once, — and it seems to me, that there is no evidence of any more plications,—indeed scarcely any evidence of one,—we shall have a thickness to this rock of ten miles; equal to that of all the stratified rocks of Great Britain, as estimated by Dr. Buckland. You know that all attempts to measure the thickness of the crystalline slate rocks of Europe have been deemed very unsatisfactory. Have you not here an opportunily to do it with a good degree of accuracy? If you can, you will convey no small favor upon geology.

The section across the southeru part of the State I found far less satisfactory. The enormous quantity of drift that is strewed over the western slope and the top of the Green Mountains, almost entirely hides the subjacent rock; so that between Bennington and Searsburgh,—that is over the main part of the range, I saw the rock in place only two or three times. The boulders are indeed gneissoid most of the way. But in the only place on the west side of the mountain where the ledges appear, they are formed of distinct mica slate; yet I must believe that gneiss occurs in the vicinity, and in great quantity. Indeed, it shows itself in Searsburgh; and it is not till you cross the Deerfield river, that you find distiuct mica slate; which, however, is succeeded again by gneiss; or rather, the two rocks appear to me to be interstratified through the whole range. I hope you will examine this region with great care; for a few miles to the south in Massachusetts, you will see, by my map, published in my Report, that I found nothlng but mica slate in the main part of the Hoosac range. In examining it, I crossed on the road from Charlemont to North Adams; and also farther north, through Monroe and Clarksburgh; and I hope you will go over the same ground: because should you represent gneiss on your map to the Massachusetts' line, there would be an apparent discrepancy between us. I incline to the belief that the rocks change in the Hoosac and Green Mountain range in the direction of their strike, as you will see by referring to my Report, (vol. 2, p. 597) and besides, much of the rock there, being half way between the two sorts, would by one man be referred to gneiss, and by another to mica slate. I believe it will be found that there is no real discrepancy between us, and that the rocks do change near the line between the two States to a considerable extent. I hope you will be able to trace out their true connection, before you publish your final Report, although I think it will require several days examination on foot in one of the most uncultivated regions of New England. I hope, also, you will do the same in respect to a deposit of singular granite in the west part of Clarksburgh, which is imperfectly described in my Report (vol. 2, p. 683.) It is possible you may find it to be thick bedded gneiss, though its boulders, strewed in immense quantity to the south-west, and sometimes fifteen or twenty feet in diameter, show no signs of lamination or stratification. As this is the only granite I have met with, connected with the Taconic rocks, its examination becomes very important.

Vermont is certainly a fine field for the study of the phenomena of drift; a subject which excites as much interest at this day as any in geology, and to which, therefore, the intelligent inhabitants of the State will wish you to pay particular attention. I

fancy the facts which you will be able to bring out, will clip the wings of some of the hypotheses that are making much noise on this subject at the present day. What fine examples of striae and embossed rocks you have along the Winooski river; where the drift agency was directly opposed to existing agencies,—the former acting with tremendous power towards the southeast and the latter moderately towards the northeast. I cannot doubt, also, that you will be able to find along the northern and western slopes of your mountains still more striking examples, in which the drift agency forced the grinding materials up hill, and that a great distance. The facts on this subject have not yet been brought out as they ought to be, for they have a most important bearing upon theory. Mere waves of translation cannot explain, it seems to me, such cases; nor can can icebergs alone, much less glaciers.

I expect, also, that Vermont will furnish interesting examples of those peculiar accumulations of drift, which I call moraines; though I would not hence infer that they were produced by common glaciers, but by any solid body urged forward by a *vis a tergo*. It seems to me, from what I have seen, that those moraines which are seen along your narrow valleys at intervals, stretching across them nearly, and often in the shape of a half moon, with the horns towards the north,—I say that I am prepared to have you show from these, that icebergs or glaciers have acted an important part in producing the peculiar phenomena of drift. I was struck the other day with the great nnmber of those moraines in Bennington county, particularly in Sunderland; and I hope that you will spend several days in examining that region.

I glanced at the economical geology of Bennington county, also, enough to be satisfied that it will require your particular attention. The region in and around Bennington appears to be rich in valuable materials for the arts. The iron beds are doubtless very numerous and rich, and with so thick a coat of drift, the wonder is that so many have been discovered. More will doubtless be brought to light. Connected with the iron is an abundance of manganese. Then there is the prolific bed of white clay, wrought by Norton and Felton; the latter of whom was kind enough to conduct me to that bed, as well as to show me his very interesting and important pottery establishment. I ought not to omit, also, the inexhaustible quantities of yellow ochre, from which a large amount of paint is annually prepared. Allow me here to make one or two suggestions concerning the white clays found in almost every town between Bennington and Monkton. I entirely agree with you in the opinion expressed in your Report of 1845, p. 53, that this clay is the result of the decomposition of calciferous slate and limestone. I have before me a specimen from the Bennington bed, where light and dark colored clays are interlaminated and plicated, so as to present a fine example of the tortuosities of the slate rocks of the Taconic range. This shows that the rock underwent decomposition in the most quiet manner. Where dark colored matter existed in the rock, it gives the same color to the clay; and when iron was present in the rock, it imparts a red color to the clay. Where only silica and alumina are present, we have the pure pipe clay, or as it has been called, *kaolin*.

But according to strict scientific principles, is this latter name correct? For the books describe kaolin as always resulting from the decomposition of feldspar. Now in no bed that I have seen, was this the case; and you say that you could not verify the statement of a previous writer, that the Monkton bed resulted from the decomposition of graphic granite. All the clays, which I have seen on the west side of the Green Mountains in Vermont, appear to me to be *pipe clay*. It is precisely the same material as that to which I have applied this name at Gay Head on Martha's Vineyard; save that at the Head the clay seems to have been rearranged by water. That the clay of Vermont will form porcelain, I doubt not; and Mr. Fenton has demonstrated it experimentally: but if we adhere to strict mineralogical principles, it should not be called kaolin.

Mr. Fenton conducted me to a remarkable spring rising in the midst of a beautiful grove in Bennington out of dilapidated drift, in such quantity as to move the machinery of a powder mill; and I was deeply interested to find that it was a *thermal spring*, like the one at New Lebanon and Williamstown: that is, great quantities of gas, (nitrogen and oxigen), were rising through the water over a space of several square rods. My belief is, that the quantity of gas is as great as, or greater than, at New Lebanon; but the water at Bennington, like that in Williamstown, and also at Clarendon, does not seem to have a higher temperature than ordinary springs, although I did not apply the thermometer. The water of this spring is undoubtedly much purer than common springs; and the hydropathist might be tempted to seize upon this beautiful spot, as he has upon Lebanon springs, for effecting water cures. But yankee enterprise has anticipated him: for a powder mill would not be a very agreeable accompaniment to such an establishment.

As I have traversed Vermont this year, I have been deeply impressed with the new era that is opening upon her by the construction of rail-roads. In a short time, if I am not greatly misinformed, all her territory east of the Green Mountains will be connected with Hartford and New York by a road through the entire valley of the Connecticut; while the State will be crossed

obliquely by two routes at least, leading to Boston, and soon, also, without doubt, will the rich mineral and agricultural districts west of the mountains open an iron track southerly into the great thoroughfares of the land. In 1830, when, as I began to survey Massachusetts geologically, I turned out of my course to see a rail-road three miles long, the only one then existing in New England, used to convey granite from the Quincy quarry to the Neponset river, how hardly should I have believed that I need wait only sixteen years to see the state cut by rail-roads in all directions! Yet such an improbability has become a demonstrative reality; and now I can easily believe that the vision of Vermont intersected by rail-roads in a similar manner will soon be accomplished—especially when I hear the spade and the drill already ringing at so many points along her valleys. And to speak of nothing else, what new outlets will such a consummation give to the mineral resources of the State. As I pass up the valley of the Connecticut, for example, I meet first with the vast deposits of roofing slates in Guilford and Dummerston, close to a railroad. Then, in similar proximity, I find the beautiful granite of Dummerston. How numerous too, are the quarries of soapstone in Grafton, Plymouth, Waterville, Stow, Westfield, Eden, Rochester, and a multitude of other places! And then, what a vast supply of serpentine, yet almost untouched, in Cavendish, Roxbury, Northfield, Troy, Lowell, Waterville, &c. Nor should the elegant brecciated marble of Plymouth be forgotten; nor the unrivalled copperas ore of Strafford and Corinth; nor the common limestone in various places, forming excellent lime; nor the fine granite of Barre—nor the granite and gneiss of the more northerly part of the State; or finally, the marls so common in the central parts of the State, almost through its whole extent. Of the rich mineral deposits west of the mountains I need say nothing, since they are already so well known.

Now who can doubt, that these rail-roads when constructed, will create a large demand for all these mineral treasures, and give new impulse to enterprises for their exhumation? And what an argument does this fact present for the vigorous prosecution of the geological survey to its completion!

I am happy to see from an inspection of your depot of specimens, what fine collections you will make out for the different institutions of the State. I hope the State will give you a reasonable time to perfect and bring out your Final Report; since not merely your own scientific reputation, but in a measure, that of the State is concerned. No one, but he who has gone through such a work, knows what an immense number of details must be attended to, nor how many doubtful points settled, sometimes not without reëxamiation,—before such a work can be properly completed. That you may live to see it finished in such a manner, is the sincere prayer of

Your friend and servant,

EDWARD HITCHCOCK.

B.

Death of Denison Olmsted, Jr.

"The funeral of this lamented young man, took place in the College Chapel* yesterday, at the close of the afternoon service. What rendered the scene peculiarly touching was, that this is the third son of Professor Olmsted, who, in the short space of two years, has been cut off in the dawn of manhood, and with the fairest prospects of usefulness. Well may the afflicted father say,

> Insatiate archer! could not one suffice?
> Thy shaft flew thrice, and thrice my peace was slain.

"The funeral services were conducted by Rev. Dr. Goodrich, from whose eloquent and appropriate address we gather the following particulars:

"It was a fact generally known to the College community, that he whose untimely fate the assembly was called to mourn, was a youth of no ordinary promise. Many present would recollect that in early childhood he developed superior mathematical powers, having become a distinguished proficient in arithmetic, and mastered the first four books of Euclid's geometry before he was nine years old. At this period, an incident apparently trifling excited in him an enthusiastic fondness for the natural sciences, particularly mineralogy and chemistry. Although, while in college, his general scholarship placed him among the most distinguished class of students, yet he never lost sight of those favorite studies, but pursued them with an affection and unity of purpose, which is a sure prognostic of eminence. He graduated at this college in 1844, and has since, until arrested by sickness, devoted himself to the study of chemistry and its kindred pursuits, with untiring zeal and energy. Although not yet twenty-two years of age, he had already acquired such reputation as to be commissioned by the State of Vermont to analyze such minerals as were selected for this purpore in the geological survey of the State,† and at almost at the very moment when the fatal malady assailed him, he was in nomination by the Geologist of the North American British Provinces, for the place of chemist in the geological survey of the Canadas: a post which he had the fairest prospect of obtaining; and which opened to him, along with the

*Yale College.

†We learn that Mr. Olmsted had also received more recently from our State Geologist, a commission as Assistant Geologist, and would have been engaged in the field labor of the survey during this summer, had not the fatal disease prevented.—[Vermont Chronicle, Sept. 2, 1846.]

rewards of honor and emolument, the fairest opportunity for professional improvement.

"To these bright prospects, and to the high hopes cherished by his friends, of distinguished success and honorable fame, a malady fatal in its character, and rapid in its advances, has put a final period. This change is the more unexpected and surprising, as he was distinguished among his fellows for muscular strength, and for athletic achievments which few could equal.

"Sad, indeed, would be such a blighting of the earthly hopes of our deceased young friend, had they not been supplanted by hopes of heaven still more exalted. At the early age of thirteen years, as many present will recollect, accompanied by a sister and three elder brothers, he came before this altar and made a solemn consecration of himself to the service of God. Although noted from infancy for his quiet, amiable disposition, and love of truth, yet so great was the change produced in his feelings when he first experienced the grace of God in his heart, that he expressed himself as happy beyond all he had ever known. Affections thus sanctified in childhood, produced their appropriate fruits in his subsequent life, marked as it was by unsullied purity, by a strict regard to truth and duty, and by exemplary devotion.

"Although his sickness was unusually distressing, yet he endured it with unexampled calmness and patience; not a murmur escaped his lips; but he blessed God for the means which he had thus enjoyed of growth in grace, and preparation for Heaven. The closing scene was peaceful and triumphant. In the hour of dissolution, the severity of his sufferings was abated, and his mind shone out with perfect clearness. "I am (said he) passing through the river—the heavenly Canaan full in view. Miracle of mercy! Infinite grace!" Many similar expressions denoted that his mind was in perfect peace. Near the close he enquired how long it was probable life would continue? and being told that he seemed very near Heaven, he said, with an expression that indicated a longing to depart, "I must not be impatient."—[New Haven Paladium, Aug. 17.

C.

Report of Mr. Denison Olmsted, Jr.

NEW HAVEN, May 4, 1846.

Prof. C. B. ADAMS,

Dear Sir:—I had the honor to receive from you last October, and at various times since, specimens for analysis, amounting in all to forty-four, upon the examination of which I beg leave to offer the following report.

The minerals were as follows:

No. 1.	White saccharoid marble,	Hyde's quarry, Rutland.
" 2.	Greenish " "	
" 3.	Claystones,	Dummerston.
" 4.	"	Addison.
" 5.	"	Alburgh.
" 6.	Kaolin,	Bennington.
" 7.	Talcose slate with specular iron,	W. Berkshire.
" 8.	Magnetic iron in ochrey iron ore,	Plymouth.
" 9.	Specular iron, micaceous,	"
" 10.	Magnetic iron in do.,	"
" 11.	Compact specular iron,	Milton.
" 12.	" "	Fairfield.
" 13.	Galena,	Chittenden.
" 14.	"	Thetford.
" 15.	Claystones,	Pittsford.
" 16.	"	Derby.
" 17.	"	Shelburne.
" 18.	"	Norwich.
" 19.	Stockbridge limestone; statuary marble,	Brandon.
" 20.	"	Bristol ore bed.
" 21.	"	North Dorset.
" 22.	Calciferous sandstone,	Milton.
" 23.	Dove-colored marble,	Swanton.
" 24.	Black marble, Hill's quarry,	Isle La Motte.
" 25.	Mica slate limestone,	Danville.
" 26.	"	Hardwick.
" 27.	"	Barnet.
" 28.	"	Craftsbury.
" 29.	"	Vershire.
" 30.	Iron ore,	Milton.
" 31.	Octahedral crystal, feebly magnetic, streak red,	Chit-
" 32.	" " magnetic, streak reddish,	tenden.
" 33.	Metallic iron and manganese, forged in	Wallingford.
" 34.	Magnetic iron ore,	Troy.
" 35.	Iron and copper pyrites,	Strafford.
" 36.	Copper pyrites,	Corinth.
" 37.	An incrustation,	Huntington.
" 38.	Galena, same with No. 14,	Thetford.
" 39.	Brown iron ore, siliceous,	Chittenden.
" 40.	Do. solid bed, average specimen,	"
" 41.	"Black ore" from which No. 33 was forged,	Wallingford.
" 42.	Psilomelane with implanted crystals, of —,	Brandon.
" 43.	————————	Bethel.
" 44.	Brown iron ore,	Colchester.

Limestones and calciferous sandstones.

1. A weighed portion of the powder, carefully dried over sulphuric acid, was boiled with hydrochloric acid until all the soluble matter was taken up.

2. The insoluble matter, consisting of silica and mica, was separated on a prepared filter and weighed.

3. The clear solution was rendered ammonical, and any alumina and oxide of iron that might be separated collected.

4. Oxalate of ammonia was added to the filtrate from the ammoniacal precipitate; the precipitated oxalate of lime collected on a filter, and after careful washing, converted into sulphate of lime, in which form it was weighed, the amount of carbonate of lime being calculated from the weight.

5. To the filtrate from the oxalate of lime, phosphate of soda was added, the mixture violently agitated, and suffered to stand for more than twelve hours, after which the phosphate of ammonia and magnesia, if present, was collected and from its weight after ignition the carbonate of magnesia computed.

[The results of these and of the following processes have been distributed through the body of the foregoing report.—C. B. A.]

In the analysis of *claystones*.

1. A gramme* of the dried powder, having been imtimately mixed with three or four times its bulk of a mixture of carbonate of potassa and carbonate of soda, was subjected in a covered platinum crucible to the full heat of an anthracite fire, until complete fusion had taken place.

2. The fused mass was treated with hydrochloric acid, and the contents of the crucible transferred to a porcelain capsule. The solution was then evaporated to dryness, the excess of acid volatilized, water added and the separated silica collected on a filter.

3. The fluid separated from the silica, was rendered ammonical, the precipitate collected on a filter, and after careful washing, removed and boiled with caustic potash. The oxides of iron and manganese left undissolved, were collected and weighed together. The quantity of manganese present in the precipitate was subsequently ascertained by a process, which will be described in speaking of the ores of iron and manganese.

4. From the potash solution separated from the oxides of iron and manganese, alumina was thrown down by chloride of ammonium.

5. From the fluid separated from the ammoniacal precipitate, lime and magnesia were obtained precisely as in the case of limestones.

* About fifteen grains.

6. Water was estimated throughout these analyses, by introducing into a covered platinum crucible, a weighed portion of the powder, carefully freed from moisture, and exposing it to the heat of an anthracite furnace, until it no longer lost weight by successive ignitions. In the case of brown iron ore, the loss gave the amount of water at once. Where carbonates were present in the original specimen, the amount of carbonic acid contained in these was computed, and being deducted from the whole loss, the remainder indicated the true amount of water present. In many cases, however, it was thought safe to estimate the water by loss on the analysis.

Iron Ores.

1. A weighed portion of the dried powder was boiled with hydrochloric acid, until all the soluble matter was taken up. In case protoxide of iron had been detected, the powder was introduced into a flask previously filled with carbonic acid, and the flask carefully covered during solution at a gentle heat, to prevent the oxidising action of the atmosphere. In case of a sulphuret, the solution was effected in nitric acid or aqua regia. Where titanium had been detected, the solution was effected in hydrochloric acid at a gentle heat.

2. After the separation of any silica that appeared, if neither protoxide of iron, peroxide of manganese, or titanic acid had been detected, peroxide of iron was thrown down at once by ammonia, collected, and after ignition, weighed.

3. The peroxide and protoxide of iron were separated by the carbonate of baryta by the process of Fuchs. Pure carbonate of baryta was added to the solution, which was made as slightly acid as possible, until all the peroxide of iron was thrown down. This, with the excess of carbonate of baryta added, was collected on a filter, and after very careful washing redissolved in hydrochloric acid: the baryta having then been separated by sulphuric acid, peroxide of iron was thrown down by ammonia, which, collected and weighed, gave the amount present in the specimen.

4. The fluid, separated from the carbonate of baryta precipitate, containing the protoxide of iron, was boiled with nitric acid until completely peroxidised, when ammonia threw down peroxide of iron, from the weight of which the amount of protoxide was calculated.

5. Manganese was separated from iron, sometimes by the above process, and sometimes by an alkaline benzoate, the iron being thrown down as benzoate of iron from an exactly neutral solution, while the manganese remained dissolved. The manganese was thrown down from the liquor containing it, after the

solution of baryta, if present, by carbonate of soda. From the weight of the carbonate of manganese after ignition, the amount of protoxide of manganese was calculated.

6. One specimen contained peroxide and protoxide of iron with titanic acid. In this case a process recommended by Kobell was followed. To the solution after the separation of a little silica, carbonate of baryta was added in excess, by which peroxide of iron and titanic acid were thrown down with the excess of baryta, while protoxide of iron remained in solution. The precipitate being separated on a filter and washed, the fluid filtered off was boiled with nitric acid, until the iron was completely peroxidised, when ammonia was added in excess, and from the weight of the precipitate the protoxide of iron computed.

The precipitate of peroxide of iron and titanic acid was redissolved in hydrochloric acid at a gentle heat, and the iron reduced to the state of protoxide by a current of sulphuretted hydrogen. After the separation of sulphur, carbonate baryta was again added, and titanic acid thrown down, while the iron was left in solution. This solution having been separated from the precipitate and peroxidized as above, ammonia threw down peroxide of iron, the weight of which indicated the amount in the original specimen.

The titanic acid was separated from the carbonate of baryta added in exess by repeated doses of sulphuric acid. From the solution it was precipitated by ammonia.

Three specimens, Nos. 10, 13, 32, were examined for a particular purpose. They consist of crystals having the form of magnetic iron ore, imbedded in specular iron. No. 10 gives a black powder and is readily attracted by the magnet. No. 31 is very feebly affected by the magnet and gives a red powder. No. 32 is somewhat more affected by the magnet than No. 31, and its powder is a shade less red. No. 10 presents on analysis the following constitution:

Peroxide of iron,	73.82
Protoxide "	26.18
Silica,	trace.

The protoxide of iron in this specimen is five per cent. less than in ordinary magnetic iron ore. This may be due in part to the penetration of the crystals by the micaceous iron of the gangue. No. 31 gave with the usual test no indication of protoxide of iron.

No. 32 showed but a feeble trace in a large amount of the solution.

Iron and Copper Pyrites.

1. A solution in nitric acid having been effected, with the exception of the pure sulphur separated during solution, and a little

silica, the fluid was filtered, and after the excess of nitric acid had been chiefly expelled, was submitted to the action of a current of sulphuretted hydrogen until completely saturated. The sulphuret of copper was separated on a filter, and after careful washing redissolved in hydrochloric acid, and precipitated by potash as oxide of copper, from the weight of which the sulphuret of copper in the specimen was calculated,—or in this instance the metallic copper.

2. The iron was thrown down as usual by ammonia, and from the weight of peroxide of iron, the sulphuret of iron, or metallic iron was found.

3. The sulphur of the original specimen having been in part converted into sulphuric acid by boiling with nitric acid, this was thrown down in the form of sulphate of baryta by the addition of chloride of barium. From the weight of the sulphate of baryta the amount of sulphur equivalent was calculated and added to the pure sulphur reserved above. (1.)

Three specimens of *galena*, Nos. 13, 14, 38, were examined for the presence of silver. Nos. 13 and 14 were treated in the moist way by a process recommended by Liebig.

1. The solution having been effected in nitric acid, with the exception of sulphate of lead formed during the operation, this was filtered off.

2. To the clear solution cyanide of potassium was added in excess. By this means all the lead was throwu down as cyanide, while the cyanide of silver at first precipated was redissolved without hesitation. The cyanide of lead having been removed by filtration, nitric acid was added in excess to the clear solution, when any silver present should have appeared as a white curdy precipitate. In the case of No. 13 not the slightest trace of silver was observed. No. 12 gave very feeble indications of its presence. Another specimen, the same as No. 14, No. 38, was afterwards subjected to cupellation, but without presenting a visible trace by this proeess, which must be regarded as far less delicate than the other of Professor Liebig.

Kaolin.

1. A weighed portion was fused as in the case of claystones, the fused mass treated with water, and filtered from the insoluble residue, which was alumina, with a little magnesia.

2. The filtrate was acidulated with hydrochloric acid, and evaporated to dryness; on treating the dried mass with water, insoluble silica appeared, which was collected and weighed.

3. The insoluble residue of (1) was dissolved in hydrochloric acid, and alumina and magnesia thrown down by the ordinary reagents.

No. 37. An incrustation from Huntington.

This was found to consist of a soluble and an insoluble portion. The soluble portion consisted chiefly of sulphate of lime, with a mere trace of sulphate of iron. No alumina was detected in the soluble portion.

No. 42. *Psilomelanite* with implanted crystals of an ore of manganese.

1. After solution the liquor was treated with hydrosulphuret of ammonia, by which all the manganese was thrown down as sulphuret. It was then redissolved in hydrochloric acid, and thrown down by carbonate of soda. From the carbonate of manganese after ignition, the amount of peroxide of manganese was computed, and the red oxide of manganese equivalent to this being ascertained, the excess of oxygen was set down as such. To other constituents were ascertained by the process already described.

D. Olmsted, Jr.

D.

Report of Mr. Thompson.

Burlington, Sept. 15, 1846.

Dear Sir,

The time at which I was expected to report to you the result of my geological examinations during the past summer, has now arrived; but the accident on the 26th of August, (of which you have already been informed, and, from the effects of which, I am now happy to inform you that I am, by the blessing of God, in a great measure recovered,) has rendered it impossible for me to place it in your hands, in season to be used in the preparation of your second annual report,. I shall, however, endeavor to have it in readiness as soon as possible, that, if it shall contain any materials suitable to your purposes, they may be available to you for future use. Not having reduced the notes which I have taken, to any order, I am not able now to give you even an abstract of my doings. My labors, when not in company with yourself, as you are aware, have been confined mostly to the county of Chittenden,—a county not hitherto regarded as promising very important discoveries, especially in the way of valuable metallic ores, or of the more choice minerals. Nor has any thing come to light during the past summer, which is calculated to produce any material change in this opinion. Still I have little doubt that iron ore, at least, of good quality, will yet be found here in considerable abundance. But, whether this expectation be realized or not, this county, I am well persuaded, contains its due proportions of mineral wealth. Quarries of excellent building stone are found in numerous places. Limestones, which make the best of quick-lime, are abundant in all the towns bordering on the lake, and there are some quarries suitable for marble, and others which make good hydraulic cement. Clays and sand suitable for bricks and pottery are common, and the sandstone formation in Colchester, I have no doubt, would furnish an abundance of excellent material for glass. The deposits of muck and peat are numerous. and some of them extensive, and there is at least one considerable deposit of shell marl. These afford the very materials needful to fertilize and give consistency to the soil of the extensive sandy plains; and. although but little used at present, their worth begins to be appreciated, and the time is probably not remote, when they will be found to be *mines* of more importance to the true interests of the country, than mines of gold or silver.

The scientific geology of that portion of the State to which my attention has been mostly confined, I have found to be exceedingly interesting, but not on account of any peculiarity of the rock formations. These are, to a great extent, the same as in the adjacent counties of Addison and Franklin, the ranges being, in many cases, continuous from south to north through the whole extent. But it is interesting on account of the numerous deposits of marine shells of the pleistocene period, some of which are more than two miles inland from the lake, and at least 200 feet above it; and especially so on account of the many proofs of igneous action from beneath at a period certainly more recent than the formation or our newest solid rocks. These proofs consist of greenstone and feldspathic dikes, the latter being usually porphyritic, which have been formed in the slates, sandstones, and other rocks, and which are exceedingly numerous, particularly in the south-western part of the county, as you will see by the specimens forwarded to you and the localities denoted on the map, which will accompany my report. On the peninsula between Shelburne bay and the lake, known by the name of Pottier's Point, I have examined more than 20 distinct dikes; but they are here more numerous, in proportion to the extent of territory, than at any other place, and the numerical ratio of the greenstone to the feldspathic dikes is about as 8 to 12. As we recede from this point, the dikes become less frequent, the greenstone dikes being the most common towards the east and north-east, as are the feldspathic towards the south. These dikes, in general, have an eastern and westerly direction, and Pottier's Point affords an excellent place to study their relative ages, and furnishes, if I mistake not, conclusive proof that the feldspathic, or porphyry dikes, are the most recent.

During the latter part of the summer I have made numerous barometrical observations; for the purpose of determining the elevation of the different parts of the county above Lake Champlain, the results of which, together with the heights of numerous points in other parts of the State, which have been ascertained by the several surveys for canals and rail-roads, will be forwarded to you with my report. I will, however, here state a few of the results obtained from my recent observations.

Mansfield Mountain, Chin,	4258	ft.	above	Lake	Champlain.
" " Nose,	3954	"		"	"
" " S. Peak,	3792	"		"	"
Camel's Hump,	3993	"		"	"
Sugar Loaf, Charlotte,	913	"		"	"
Snake Hill, Milton,	822	"		"	"
Cobble Hill, do.	737	"		"	"
Underhill Flat,	575	"		"	"

These measurements make the Chin and Nose each about 70 feet higher, and Camel's Hump 100 feet lower than the results of Capt. A. Partridge's barometrical measurements made several years ago. E. F. Johnson, Esq., by trigonometrical observations made at Burlington, calculated the height of the Chin to be 4269 feet above the lake, and I am informed that some of the engineers employed on the Central Rail-Road have found the height of Camel's Hump, by levelling up it, to be 3984 feet above the lake. Very respectfully and truly yours,

ZADOCK THOMPSON.

E.

Letter from Dr. C. L. Allen.

MIDDLEBURY, VT., Sept. 21, 1846.

Prof. ADAMS,

Sir:—Having recently visited and analysed qualitatively the water of a spring, situated on the farm of Solomon Allen, in Panton, I forward to you the results of the analysis.

The substances contained in the water are,

Sulphate of magnesia,	Sulphate of soda,
Sulphate of iron,	Carbonate of lime,
Carbonate of soda,	Carbonic acid gas.

Of these, the sulphate of magnesia [Epsom salts] exists in the largest quantity; probably, to the amount of half a drachm in a pint. The iron and carbonates are in small quantities. There are about five cubic inches of carbonic acid in a pint of the water. Your obedient servant,

C. LINNAEUS ALLEN.

F.

Expenses of the Survey.

The expenses of the geological survey, from March 1, 1846, to October 1, 1846, have been the following:

Travelling expenses of principal and assistants,	$358.27
Salary of the Principal,	350.00
Salaries of commissioned assistants,	324.00
Services of occasional assistants,	90.42
Services of President Hitchcock,	54.00
Apparatus, engravings, and expenses of the geological depot, including rent, fuel, mineral trays, &c.	222.12
Transportation and postage,	64.42
	$1463.23

The estimates for the remainder of the year, up to March 1, 1847, are the following:

Travelling expenses,	$20.00
Salary of the Principal,	250.00
Services of occasional assistants,	32.77
Expenses of the geological depot,	20.00
Transportation and postage,	14.00
Chemical analyses,	200.00
	536.77
	$2000.00

If the funds of the survey for the ensuing year should not be increased, the expenses of the current year may be taken as the estimates, which are required by law.

The analyses of soils is an important object of the survey, to which we have alluded in the introduction to this report. In order to show the nature of this work, I insert here extracts from a correspondence with Mr. Benjamin Silliman, Jr. Professor, in Yale College, of Chemistry applied to the arts.

"I hardly know what answer to make to your enquiry about the terms for analyzing one hundred specimens of soils, &c. Our customary charge in analysis has been $5 per every determinaiion. This makes a round bill, but not more than a fair quid pro quo for the labor and skill required. It is the rate affixed by the joint agreement of several chemists. However we always make an abatement from it in case of many analyses of the same sort. No doubt, *a sort of analysis* of a soil may be made for $5 all told, but what sort I will not say. In my opinion the present srate of science demands that an analysis of a soil to be of any use whatever, must be minute, and ought to comprise at least ten separate determinations, besides the *ultimate* analysis of the whole mass, by alkaline fusion, which is useful as showing the extreme resource of the soil. We now think that we must have, *first*, an analysis of the matter soluble from the soil *by water* alone. *Second*, the amount of the matters soluble in dilute hydrochloric acid. *Third*, the amount of organic matters, and the hygrometric capacity of the soil, and, *Fourth*, the ultimate analysis by fusion, as just suggested. *Lastly* we ought to know the *mechanical* condition of the soil, technically called its *mechanical analysis*, which requires a series of siftings, washings and weighings, distinct from all the proceeding. Going through all these numerous but essential steps on sixteen soils for * * * we made him a bill of $500. The difference between fertility and barrenness is comprised within such narrow limits that only a minute analysis of the sort I have sketched, can be of much use. Agriculture gains nothing from any further multiplication of such analyses, as the bulk of those which in past years have filled geological and agricultural reports. We have enough such already. Unless an analysis of a soil can do something more than people have hitherto been content with, the result will soon be, that agriculturists will with reason, question the utility of chemical analyses as of any practical benefit."

The expenses of the analyses of one hundred soils, not including the services of the chemist, are estimated by Professor Silliman at $400, which is certainly a low estimate for a work of such magnitude. Having received some assurance that most of the ordinary compensation for the skill and time of the chemist would be dispensed with, I should have taken measures, had the funds of the survey permitted, to secure the invaluable services of this distinguished chemist.

The accumulation in the geological depot of about 12.000 specimens—of which only one fourth have been prepared for distribution, by the laborious process described in the introduction to this report,—will be the occasion of an increased expenditure, which will, however, be small in comparison with the value of the results.

The last year of the field labor of the survey must necessarily be attended with increased expenditure, for several important objects, which will form the subject of a future communication to the Executive.

NOTE.

In this Report the bearings of compass are corrected for variation, 10° W. being allowed. The variation at the N. E. corner of the State is 12° W., at the N. W. part 11° W., as determined by the U. S. Engineers on the boundary line. At Burlington about 10°, according to Mr. Thompson. We are informed, in the south part of the State, that the variation was 9° W.

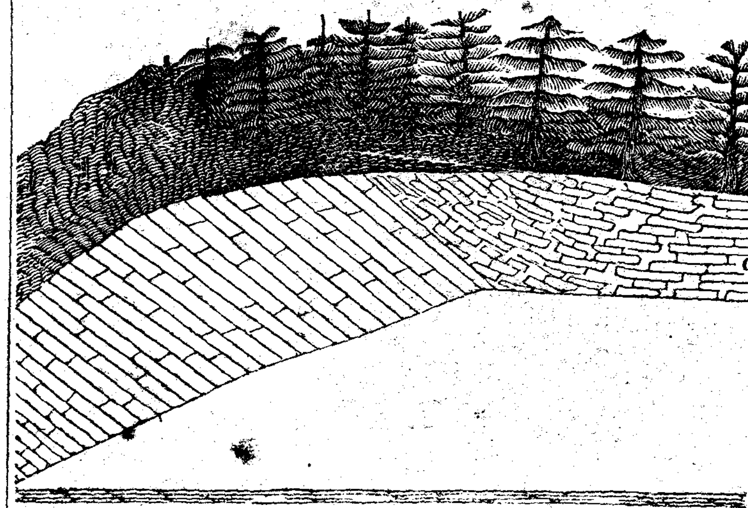
GLOSSARY.

EXPLANATION OF TERMS.

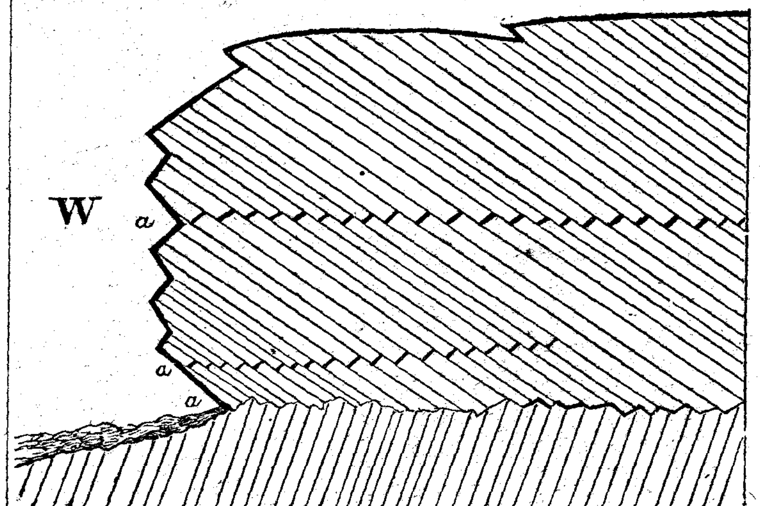
Actinolite, a variety of hornblende in long slender green crystals.
Adit, an entrance to a mine nearly or quite horizontal—usually a little ascending, for drainage.
Alkali, a chemical agent which is caustic and neutralizes acids, as potash.
Amethystine, of the color of amethyst, a violet variety of quartz, used as a gem.
Anthracite, mineral coal which is not bituminous, & burns without smoke.
Anticlinal axis, an imaginary line in the rocks, from either side of which they dip in opposite directions.
Apocrenic acid, an acid found in the mould of soils.
Aqueous, relating to water. Rocks of aqueous origin are those which were deposited by water as sediment.
Arenaceous, crumbling into sand.
Argentiferous, containing silver.
Argillaceous, containing or composed of clay.
Augite, a variety of hornblende.
Azoic, destitute of organic remains.
Bed, a layer of mineral matter included between the layers of rock.
Binary, containing two ingredients.
Botryoidal, resembling a bunch of grapes; consisting of aggregated globules.
Boulder, a fragment of rock which has had its angles worn off.
Breccia, a mass composed of angular fragments.
Brown coal, a variety of mineral coal resembling charred vegetable matter, of little use.
Brown Hematite, a fibrous variety of brown iron ore.
Cainozoic, containing remains of some of the existing or the less ancient species of animals.
Calcareous, composed more or less of carbonate of lime.
Calciferous, containing carbonate of lime.
Carapace, a shelly covering on the back of some animals.
Carbon, an elementary substance of which coal is chiefly, and the diamond entirely composed.
Carboniferous, containing coal.
Chlorine, a yellowish green gas, very corrosive and destructive when breathed, with remarkable bleaching properties.
Chlorite, a dark green soft earthly mineral.
Chlorite slate, a kind of slate composed of grains of chlorite and quartz.
Compact, composed of grains which are nearly or quite invisible to the naked eye, and more or less firmly coherent.
Conchoidal, with concavities in the surface.
Concretion, see p. 11.
Congeners, those which belong to the same genus.
Conformable; strata are said to be conformable when they lie parallel with each other.
Conglomerate, a rock composed of pebbles and gravel consolidated.
Coniferous, bearing cones, like pine trees.
Coral, a rocky mass formed by secretions from minute animals in the warm ocean of tropical climates.
Coraliferous, producing coral.
Corpuscular, relating to particles of matter.
Crenic acid, an acid found in vegeta-

ble mould.
Crystal, a mineral body with a regular symmetrical form.
Crystalline, composed of crystals.
Crystallization, the act of forming into crystals.
Debris, an accumulation of angular fragments of rock.
Denudation, the wearing away of the surface.
Desiccation, a drying up.
Detritus, that which is worn off.
Dip, inclination of the strata below the plane of the horizon.
Disintegration, a crumbling into fine imperceptible particles.
Dolomitic; Dolomite, or a dolomitic limestone, is one which contains magnesia.
Drift, see p. 91; also a passage in a mine.
Dyke, see p. 160.
Elytra, the hard wingcases of beetles and of other insects.
Encrinite, an animal composed in great part of a calcareous skeleton, affixed to the bottom of the sea by a jointed stem, with a flower-shaped summit.
Endogenous, see p. 59.
Excentric, proceeding from a centre.
Fauna, the animals of any country or period.
Feldspathic, consisting, more or less, of feldspar.
Flora, the plants of any country or period.
Formation, layers of rock which were deposited during the same period of the earth's history.
Fossil, found in the rocks of earth; the term is usually applied only to the remains of plants and animals.
Fossiliferous, containing fossils.
Fucoid, a fossil resembling sea-weeds.
Gangue, the mass in which a mineral is embedded.
Geine, a name applied by some to vegetable mould.
Gneiss, a stratified rock which is composed of quartz, feldspar and mica.
Granite, an unstratified rock composed of the same ingredients as gneiss.
Granular, composed of grains.
Graphic, resembling written characters, as graphic granite.
Graphite; black lead is the common but improper name.
Greenstone, an ancient volcanic rock.
Hematite, fibrous iron ore.
Hornblende slate, a slate composed of grains of hornblende and quartz.
Humic acid, an acid found in vegetable mould.
Humus, vegetable mould.
Hypogene, formed deep in the crust of the earth.
Ichthyosaurus, see p. 100.
Igneous; an igneous rock is one which was erupted in a melted state, like lava.
Interstratified, lying between the strata.
Joints, planes of division cutting across strata, with smooth faces.
Lacustrine, pertaining to a pond or lake.
Lamina, a thin plate of any thing, as of mica.
Lava, the melted matter of volcanoes.
Lithological; the lithological characters of rock are their mineral characters, in distinction from position and fossil contents.
Littoral, inhabiting the shore.
Maclurea, a genus of marine shells, long since extinct, somewhat resembling, in form, snail-shells.
Mammillary, having a surface covered with small convexities.
Mesozoic, containing the remains of animals which lived in the middle periods of the geological history.
Metamorphic, changed by heat to a crystalline structure.
Mica slate, a slate composed of grains of mica and quartz.
Nodule, a lump more or less globular.
Octahedral, having eight three-sided faces.
Oolitic, see p. 98.
Organic; all animal and vegetables bodies are said to be organic, because composed of organs or vital apparatus.
Orthocera, a genus of shells long since extinct, straight and conical, and divided into numerous chambers by tranverse partitions.
Oxide, a substance combined with oxygen gas, and not acid, is anoxide; thus oxide of iron is the metal iron combined with oxygen.
Palæozoic, containing ancient animals.
Pluvial, pertaining to rain.

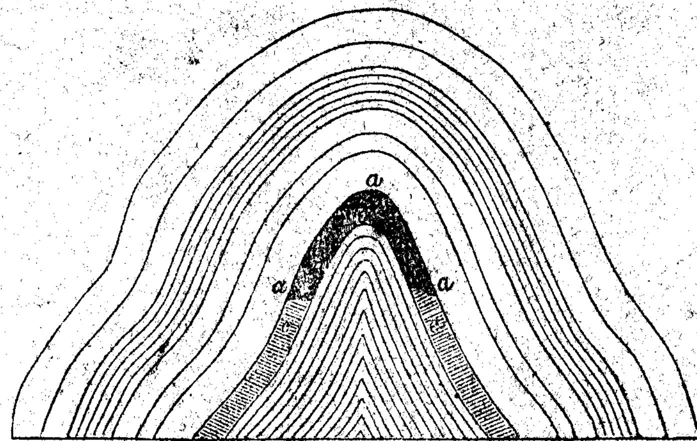
Pollen, the dust in flowers, which is essential to reproduction.
Pelagic, inhabiting deep water.
Plumbago, see graphite.
Polyparia, corals.
Primary; primary rocks are the oldest rocks.
Pseudomorphism, the substitution for the crystalline form proper to any mineral of a form proper to some other mineral.
Reverberatory; a reverberatory furnace is one in which a dome reflects the flame down on the ore.
Saccharine, sugary.
Saccharoid, resembling white sugar.
Sandstone, a rock composed of grains of sand more or less firmly coherent.
Saurians, animals allied to alligatars, &c.
Secondary, see table, p. 84.
Shale, soft slate.
Siliceous, more or less composed of silex or quartz.
Sphagnous, abounding with sphagnum, a kind of moss.
Stalactites, mineral substances in the shape of icicles.
Steatite, soapstone, sometimes called freestone improperly.
Strike, direction of the upturned edges of the strata.
Streak, the color obtained by filing mineral.
Synclinal axis, an imaginary line towards which the strata dip from either side,
Talc, the softest mineral.
Talciferous, containing talc.
Taconic, an Indian name of a range of mountains next west of the Green Mountains in south-western Vt. and Mass., now applied to the rocks next west of the Green Mountains.
Talcose slate, a slate composed of grains of talc and quartz.
Tertiary, see table, p. 84.
Translucent, admitting of the passage of light, less than transparent.
Tufa; calcareous tufa is a deposit of carbonate of lime, (limestone) from water which held it in solution.
Tympstone, in an iron furnace, the stone beneath which the melted iron is drawn off.
Unconformable, not conformable, which see.
Veins, long masses of mineral matter, which have been injected into rocks by igneous agency; or which have been separated otherwise from the contiguous rock.
Vitreous, resembling glass.



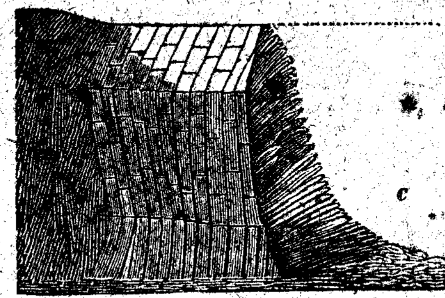
Fractured slate in the summit of Bruce's quarry, Guilford.



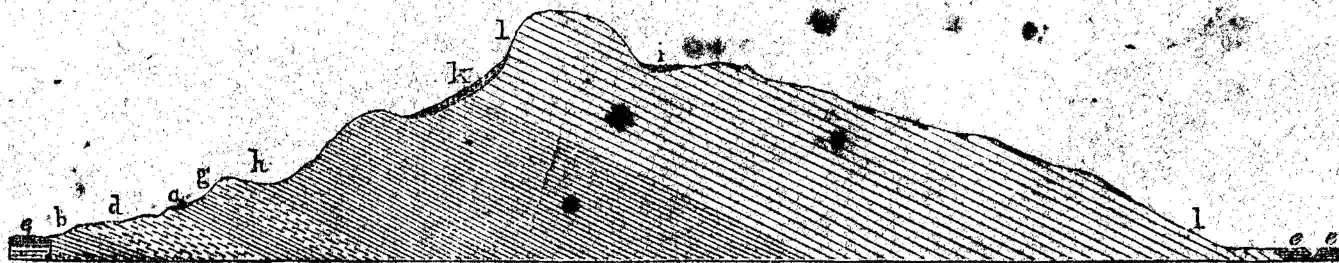
Fractured slate at the north end of Bruce's quarry, Guilford.



Section of the arch of a plication of red sandrock, Monkton.



Fractured slate hill, Willard's quarry, Guilford.



Section of the palaeozoic rocks of Vt., in Snake mountain, Addison Co.