REPORT

OF THE

STATE GEOLOGIST

ON THE

MINERAL INDUSTRIES AND GEOLOGY

OF

VERMONT

1915-1916

TENTH OF THIS SERIES

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University of Vermont

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TABLE OF CONTENTS.

LIST OF PLATES.

FIGURES IN THE TEXT.

STATE OF VERMONT.

OFFICE OF STATE GEOLOGIST.

BURLINGTON, VT., December 30th, 1916.

To His Excellency, Charles W. Gates, Governor of Vermont:

Sir:—In accordance with Section 279, Statutes of 1900, I herewith present my Biennial Report as State Geologist.

During the two years included in this Report, 1915-1916, the work of the Survey begun in former years has been extended over additional areas and considerable progress has been made toward a knowledge of the geology of the entire State.

The geological history of Vermont is so complex and the appropriation available is so limited that the work must necessarily be slow. After the close of the Survey under Dr. Hitchcock which completed its report in 1861, no work of any importance was done in investigating the geology of the State until 1898.

Since 1898 the work has been continuous and it is hoped that in a few years it may be possible to give a more or less full account of every part of the State.

The Survey alone could not do this, but by the aid of numerous volunteer assistants who have become interested in our many problems and who every year are freely contributing valuable material, we may expect more speedy results than would otherwise be possible. The Topographic Survey of Vermont, which has been carried on by the United States Geological Survey in cooperation with the State Survey is being extended as rapidly as the funds appropriated will allow. Nearly half of the entire State has been surveyed and maps of more than a third have been published.

The usual routine work of the office has been completed.

Very respectfully,

G. H. PERKINS,
State Geologist.

INTRODUCTION.

The present Report of the Geology of Vermont covers a somewhat wider range of subjects than most that have preceded it and is more largely devoted to surface geology.

The first three articles in the volume deal almost wholly with what may be called Physiographic Geology and will be found of great value by those interested in this phase of the subject. The Geologist considers it a bit of very good fortune that such recognized authorities as Professors Fairchild and Goldthwait have been willing to contribute their services freely to the work of the Survey and to prepare papers of permanent value on the surface geology of the areas which they have chosen to investigate. In a somewhat different field, the article by Mr. D. P. Jones also deals mainly with surface geology and supplements previous work carried on by Professor Richardson in the same region. Professor Richardson, who for many years has been connected with this Survey, has been moving from the extreme northern part of the State south, taking up the geology of the towns east of the Green Mountains in order, has during the past two years brought his explorations south to and including Montpelier and Berlin. As his article shows, he has been very successful in finding fossils, graptolites, in numerous localities in which hitherto no fossils of any sort have been discovered and has thus settled the age of considerable masses of the rocks of eastern Vermont.

Through these discoveries it seems probable that the disputed age of these beds may be definitely determined.

The List of Altitudes in Vermont will be found convenient for reference by the many desiring to know the relation of localities to sea level.

Professor E. C. Jacobs gives an interesting summary of what has up to date been accomplished in Copper Mining in Vermont. Elsewhere in the volume Professor Jacobs continues his discussion of the character and origin of talc and serpentine begun in the Report immediately preceding this.

Taken together these papers form a very important treatment of the rocks considered as well as a valuable addition to the geology of Vermont.

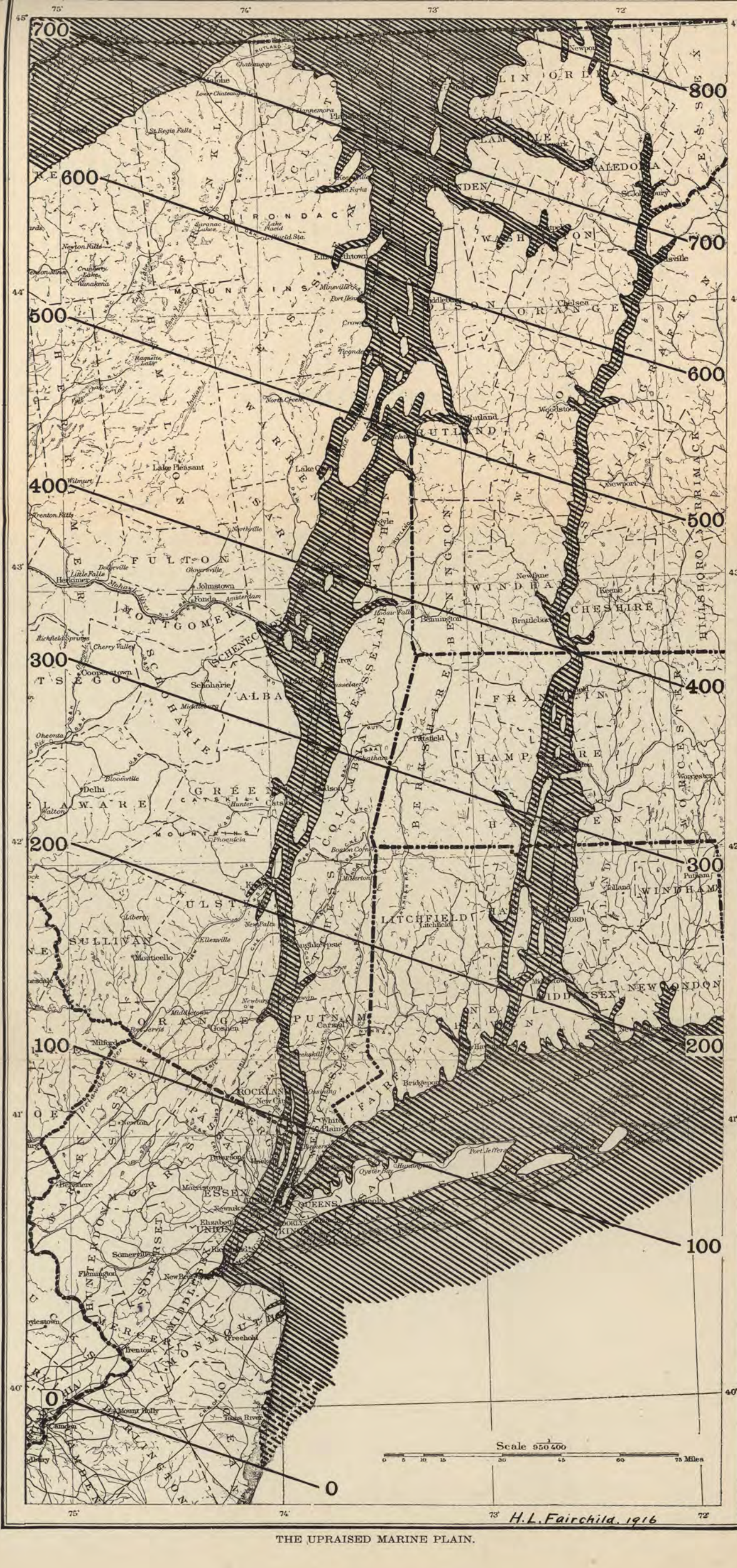
At the request of the Geologist, Mr. Harold Ladd Smith of the Vermont Marble Company has written an account of the new lime plant which this company has installed at West Rutland, illustrated by cuts supplied by the company.

A general account of the Geology of Western Vermont by the Geologist will be found useful by anyone wishing to study the geology of any of the towns mentioned in the article.

Mr. Edward Wigglesworth has contributed a paper which gives a report of his studies in the Serpentine Areas of the State. This paper is a valuable addition to the study of these rocks by Professor Jacobs.

A brief report on the present condition of the stone industries of Vermont closes the volume.

As this Report is Tenth in the series published by this Survey, it may be a convenience to readers to find at the close of this volume an Index to the entire set and this has been prepared.



THE UPRAISED MARINE PLAIN.

POST GLACIAL MARINE WATERS IN VERMONT

HERMAN LEROY FAIRCHILD,

Professor of Geology, The University of Rochester.

CONTENTS.

INTRODUCTION.

That oceanic waters lay over the lower stretches of the Champlain and St. Lawrence valleys since the latest ice sheet of glacial time disappeared has been recognized for nearly a century. The occurrence of marine fossils in abundance in the lower sands and clays was sufficient proof of the salt water invasion, but the depth of the sea water, or the amount of the continental depression, has been a subject of study, with diversity of opinion. Some of the early geologists thought that New England was depressed a few thousand feet below its present level. Doubtless they mistook the high-level glacial gravels for oceanic deposits. In the latter part of the past century it was recognized that the glacier served as a dam across valleys and land depressions and so produced ice-dammed waters or glacial lakes, at various altitudes. The splendid ancient shore lines about the Great Lakes which had been interpreted by Roy (1837), Lyell (1842) and some American geologists as marine beaches were found to be the records of glacial lakes.

The broad stretches of sand plains on both sides of the Champlain valley, and conspicuous in Vermont, are clear evidence of standing water at levels far above Lake Champlain. Marine fossils found in large numbers up to a height of over 300 feet on the parallel of Burlington leave no chance for doubt as to the sea level origin of the lower plains. But the absence of well-attested fossils in the higher sand plains has led some geologists of recent years to assume that glacial lake waters were responsible for the higher plains. This is certainly an error. The terraces, beaches and shore phenomena in the open Champlain valley were produced by waters confluent with the sea. As this report will show, the summit marine plane lies uplifted today about 400 feet above tide at the south edge of Vermont and about 800 feet at the north border of the State.

For the reader who is a beginner in the science of geology it may be explained that the up-and-down movement of great areas of the earth's surface is one of the most evident and fundamental facts of geology. Vast areas which are now many thousands of feet above sea level are composed of rock strata originally deposited as beds of clay or sand in the ocean. The time involved in these slow continental movements may be millions of years. The few hundred feet of vertical uplift involved in the recent history of Vermont is insignificant in comparison with earlier movements in the same region. Its importance or significance lies in the fact that it is the very latest event in the geologic history, the uplift having taken place within the last few thousand years, and possibly not yet entirely ceased.

These static-water phenomena have been observed by several geologists and discussed in publications listed in the appended bibliography. In the Champlain area credit is specially due to Professor Charles H. Hitchcock, who has noted many of the features described in the present writing. Professor J. J. Stevenson has contributed a list of altitudes, incorporated in Hitchcock's paper, number 9 of the bibliographic list. The glacial lake history has been briefly discussed by H. E. Merwin, in number 28.

In the Connecticut valley area detailed studies were made long ago by Professor James D. Dana (15), and by Warren Upham (10-14). The Massachusetts section of the Connecticut valley has been very thoroughly studied by Professor B. K. Emerson and described in two papers (23). Excepting Professor Emerson, the students of this subject have failed to recognize the summit-level features and to trace the summit plane. This failure and the confusion of the sea level phenomena with glacial lake features has led to inconclusive and unsatisfactory results.

The writer wishes to make this report useful to the people of Vermont, specially to the teachers and advanced pupils of the High Schools and Colleges, particularly in the areas where the marine phenomena occur. With this object in view much of the text will be popular in manner rather than technical.

Fortunately for the study of the sea level water we have for nearly all of the territory involved in western Vermont the elegant, detailed topographic maps published by the U. S. Geological Survey in cooperation with the Geological Survey of Vermont.[1]

If the readers of this paper can have at hand the following sheets published by the U. S. Geological Survey the physical features mentioned will be very much more clearly understood.

The maps needed are the following:

Rouses Point, Plattsburg, Willsboro, Port Henry, Ticonderoga, Whitehall, St. Albans, Milton, Burlington, Middlebury, Brandon, Rutland, Castleton. At depositories of the maps a key map which shows the location of the different sheets may be obtained gratis.

The first six, though New York sheets, are useful to Vermonters since they all extend eastward to include some of the Vermont territory.

GENERAL STATEMENT.

A brief statement of the sequence of events and of the origin of the geologic features will help the reader to better appreciation of the more detailed description to follow.

The latest of the ice sheets, the Labradorian glacier, covered practically all of New York and New England, reaching to Staten Island, below New York City. As the ice body waned and the front of the glacier receded northward the oceanic waters followed and occupied all the land area beneath the sea level that the ice abandoned. This was true not only of the Hudson valley but of the Connecticut and other valleys of New England. At that time the land was much lower than today, having been depressed, probably, by the long-continued pressure of the thick ice body. The thickness of the ice is estimated as not less than 10,000 feet at the north boundary of Vermont. The amount of the land depression below the present level is shown by the height to which the marine shore lines have since been lifted

[1] These maps may be obtained from the following:—Bennington: E. T. Griswold, Stationery and Miscellaneous; Brattleboro: Clapp & Jones, Books and Stationery; Burlington: L. W. Fennell, Custom House; Chester: National Survey Co.; Rutland: The Tuttle Co., Booksellers and Stationers; Woodstock: W. H. Moore, The Vermont Standard; or they may be purchased from the Director U. S. Geological Survey, Washington, D. C. Single maps cost ten cents each, but fifty may be bought for three dollars and there may be as great variety as the purchaser wishes.

above sea level. We find that the uplifted marine plane rises northward from zero, below New York City, to 500 feet at Rutland and to 740 feet at St. Albans, and 740 feet at Lyndonville in the Connecticut basin. As the sea level waters followed the retreating ice front up the Hudson valley they formed a narrow strip of water which we may call the Hudson Inlet. Stretching further north it became the Hudson-Champlain Inlet. When the ice melted away from the high ground northwest of Plattsburg, at Covey Hill, the sea level waters took possession of the St. Lawrence valley and Ontario basin, and these expanded waters have been named the Champlain sea. The western part of this sea, which occupied the Ontario basin, as successor to the great Lake Iroquois, has been named Gilbert Gulf. Up to this time and for a long time subsequent the ice lay against the high ground of Maine and New Brunswick and prevented the union of the Champlain sea with the open ocean on the east. When, eventually, the ice front did weaken on that ground and permitted the confluence of the Gulf of St. Lawrence and the Champlain sea then the Hudson-Champlain Inlet became the Hudson-Champlain Strait.

The Connecticut valley was also flooded by waters at sea level and had a history similar to that of the Hudson, except that it was closed at the north. The sea level water followed the receding ice front up the valley, along the east side of Vermont, to as far north as Lyndonville in the Passumpsic river valley. Here the marine plane is about 740 feet, the same as at St. Albans. This extension of the sea may be called the Connecticut valley inlet.

The maps, Plates I, II, show in a generalized way the area flooded by the marine waters and the approximate location of the highest shore lines. The solid lines across the map are lines of equal uplift (isobases) and indicate how the ancient sea plane has been tilted and warped. The rate of uplift or gradient is over 2.5 feet per mile in north and south line.

ABSENCE OF MARINE FOSSILS IN THE HIGHER DEPOSITS.

As animals from the sea are found abundantly in the lower sands and clays and are wanting in the upper deposits it was not illogical to doubt the marine origin of the upper deposits. The error was in assuming that all sea level waters, even the highest, must be saline or truly marine in the biologic sense.

The absence of marine fossils from the higher deposits of the sea level waters is readily explained. The earlier and higher waters were fresh waters. They were confluent with the sea, and therefore sea level, but not saline. The Hudson is sea level, with tides felt up to Albany, but is merely brackish water to about the highlands, at West Point. As long as the glacier shut out the salt water of St. Lawrence Gulf all the copious waters derived from the land drainage and from the melting of the extended front of the glacier were forced south through the narrow passes at Whitehall and West Point. After the ice front passed north of Albany all the outflow of the Great Lakes area passed out through the Mohawk valley and the lower Hudson. When the ice front backed away from the Covey Hill salient the Great Lakes outflow was simply shifted from the Mohawk outlet to the Covey Hill passes. There was a strong outflow of cold fresh water southward which excluded marine fauna.

The sea level waters in the Connecticut valley were also freshened by the glacial flood. The narrow connection with the sea through the straits at Middletown and New Haven prevented the free entrance of salt water and marine life.

When the ice barrier in the Maine district was broken saline waters freely entered from the east. Then the Hudson-Champlain Strait was open to the sea at both ends and marine life became abundant in the St. Lawrence and Champlain area. But even then the marine forms do not seem to have existed in the Hudson valley. This is explained by another and most important factor in the history. From the time when the waters built the highest beaches in Vermont and New York until the time when connection was opened to the St. Lawrence Gulf was a span of probably several, or many, thousand years. During this period land uplifting was in progress over the areas that had been relieved of the ice burden. By the time that the marine fauna entered the Champlain valley the earlier beaches had been raised far above the level of the sea. Only lower levels were at ocean height when tide and wind swept salt water animals west and south to Vermont territory.

The upper limit of marine fossils has not been determined with precision. They occur in abundance in the region of Plattsburg up to 340 feet above tide. In Vermont the verified occurrences reach up to 300 feet.

It is possible that before marine life became established in the southern part of the Champlain valley the land uplifting had raised the divide near Fort Edward above the water level and so permanently excluded the sea fauna from the Hudson valley. This would have required a lifting of 300 feet. The total uplift there is about 450 feet.

GLACIAL LAKES INCOMPETENT.

As glacial waters have been assumed in explanation of the higher water features in the Champlain valley (27) it is well to give briefly the facts which rule glacial lakes out of consideration.

Glacial lakes, like any other lakes, require outlets. The outflow channel determines the water plane and it must correlate with the shore lines. Any waterbody which had sufficient length of life and persistence of level to produce the higher heavy beaches in New York and Vermont, and had also the great volume of outflow, augmented by the melting of the vast ice sheet, must have developed a large and conspicuous outlet channel. The suggestion has been made (13) that the New York City district was elevated so as to constitute a land barrier. As the summit shore line lies above sea level at New York any land blockade would have to be out beyond the present seashore. The supposed outlet channels, thought to exist on the west side of the Hudson valley south of Schuylerville and across the divide near Fort Edward, are static-water features and are not channels (27). They have no essential characters of river channels but are the product of standing waters. At these localities very conspicuous terracing by standing water is seen on both sides of the valley far above the supposed channels. The Fort Edward divide is 150 feet in altitude while the strong shore features are over 400 feet.

The only possible glacial lakes in the great valley would be marginal to the ice lobes, held between the side of the glacier and the valley walls. Such small lakes were short-lived, inconstant in level and generally incompetent to produce strong and extensive shore lines. Between the individual lakes there would be no relationship of level. The glacial lakes on the Vermont side of the Champlain valley will be considered later. (See page 36).

TERMINOLOGY.

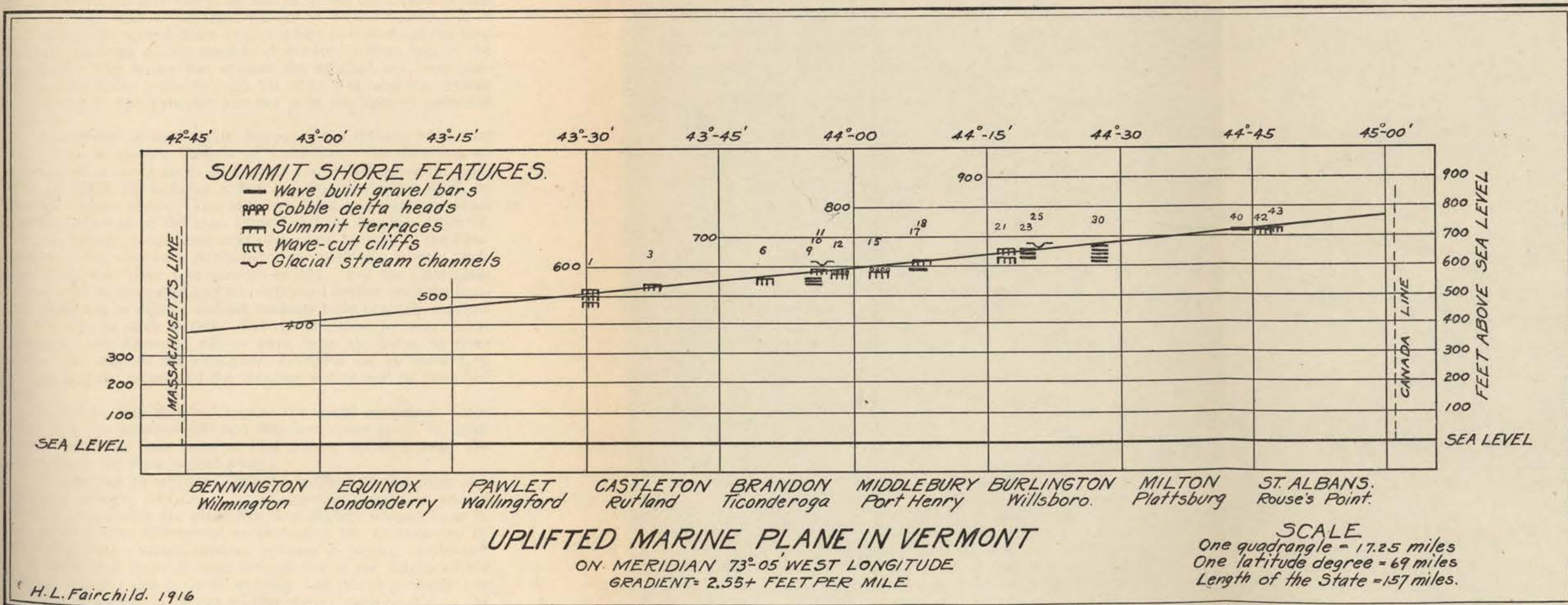
In this writing the waters confluent with the sea are usually called sea level waters. For variety in expression the terms "marine" and "oceanic" are sometimes used, but it must be understood that these terms are not intended to imply salinity of the waters or the existence of a salt water fauna.

The name "Lake Albany" as applied to the waters in the upper Hudson valley might not be seriously objectionable if the reader clearly understood that the waters were confluent with the open sea. The name was given with the conception of a glacial lake (27). The name "Lake Vermont" as applied to the Champlain valley waters is objectionable for the reason that these waters were only the northward expansion of the Albany waters. As the term "Lake" was applied in the view that the waters were glacial, with independent levels, and as the term is commonly misleading it is better not used. It is better to speak of the "Albany waters," "Hudson waters" or "Champlain waters," since these terms are non-committal as regards their character and relations. The term "Champlain Sea," originally used by Upham, is entirely appropriate for the broad waters of the St. Lawrence and Champlain area, and is used in this writing.

EXPLANATION OF THE DIAGRAM, PLATE II.

This diagram shows the altitude and slope of the uplifted marine plane, along the meridian of seventy-three degrees and five minutes of west longitude. This line passes through Brandon, East Middlebury, Bristol and St. Albans. The shore features that are indicated are a part of the phenomena produced at the summit level of the sea level waters. The only exceptions are numbers one and two, which lie a few miles away from the meridian but which are given the position for their isobases. The numbers refer to the following description.

1. Delta of Poultney River, at Poultney; 520 feet altitude above sea level.
3. Delta terraces in the City of Rutland, and in the valley south, 540 feet.
6. Broad lower plain at Forestdale, 560 feet.
9. Gravel bars on south end of Brush Hill, two miles south of East Middlebury, 560-540 feet.
10. Delta filling, head of Lake Dunmore, 590 feet.
11. Glacial river channel, ice-border drainage, west side of Bryant Mountain; lowest flow, 600 feet.
12. Salisbury Cobbleplain, one and one-half miles south of East Middlebury, 580 feet.
15. "Cobble" Cobbleplain, five miles northeast of Middlebury, 590-580 feet.
17. Gravel bars on the Bristol delta, south side of New Haven River, 595 feet.
18. Bristol delta, by the New Haven River; summit 620 feet, the village plain 610 feet.
21. South Hinesburg delta, by Hollow Brook; terraces 660, 630 feet (by the topographic map).
23. Gravel bars, west side of road, two miles southeast of Hinesburg, 660 down to 620 and lower. A heavy delta one mile north of the bars is about 670 feet by the map.
25. Glacial stream channel two miles east of Hinesburg has mouth at about 680 to 660 feet. The flow of this stream built the delta noted under 23.
30. Bars and cliff on the east and south faces of North Hill, two miles north of Williston, ranging from 670 feet down to 611.
40. Weak, summit wave-work by School 14, and surrounding district, 720 feet and lower.
42. Delta and wave-work by the St. Albans reservoir, west of School 9, at 720 feet and lower.
43. Delta summit at Swamp School, four miles southeast of St. Albans, 725 feet.


42°-45'
43°-00'
43°-15'
43°-30'
43°-45'
44°-00
44°-15'
44°-30
44°-45
45°-00'
SUMMIT SHORE FEATURES.
Wave built gravel bars
Cobble delta heads
Summit terraces
Wave-cut cliffs
Glacial stream channels
MASSACHUSETTS LINE
CANADA LINE
SEA LEVEL
100
200
300
400
500
600
700
800
900
FEET ABOVE SEA LEVEL
BENNINGTON
Wilmington
EQUINOX
Londonderry
PAWLET
Wallingford
CASTLETON
Rutland
BRANDON
Ticonderoga
MIDDLEBURY
Port Henry
BURLINGTON
Willsboro.
MILTON
Plattsburg
ST. ALBANS.
Rouse's Point.
UPLIFTED MARINE PLANE IN VERMONT
ON MERIDIAN 73°-05' WEST LONGITUDE
GRADIENT = 2.55+ FEET PER MILE
SCALE
One quadrangle = 17.25 miles
One latitude degree = 69 miles
Length of the State = 157 miles.
H. L. Fairchild. 1916

THE UPLIFTED MARINE PLANE.

It is evident that the sea level records in Vermont must be studied in comparison with correlating phenomena on the New York side of the Champlain depression, and the full interpretation requires extended comparison of similar features the whole length of the Hudson valley, as well as of the St. Lawrence and Ontario basin and of adjacent valleys in New England. It is certain that the up and down (diastrophic) movement of the land through hundreds of feet must have involved a large area of the continent. The writer has studied the uplifted sea level phenomena for many years through the wide area, and the present description of the Vermont features is in the light of extended studies.

The center of land uplift, following the melting of the ice sheet, was in eastern Canada or Labrador. The direction of steepest tilt is about north 20 degrees east, which gives the lines of equal uplift, the isobases, a direction east 20 degrees south by west 20 degrees north. The upraised, tilted and warped marine plane is indicated by the map, Plate I and the diagram, Plate II.

The broad, conspicuous sand plains and terraces in the Connecticut valley were once attributed to the work of a greatly swollen Connecticut river (see account in 15). For the Champlain valley, with its wide area and its northward decline such explanation could not be offered and all students have properly credited the features to static waters. But the abundant terraces in the Winooski and Lamoille valleys have been attributed to river work. The summit sea level plane extended far up these deep valleys, and the records of the standing waters will be described later.

It will be seen that in Vermont the initial or summit water plane now lies between 400 and 800 feet above tide. In other words the State has been to that extent uplifted since the Labradorian ice sheet melted away.

It must not be supposed that the uplifted marine plane is a perfectly straight surface, or even a perfectly uniform curved surface. Apparently the plane has been slightly warped so as to give a northward differential or increasing tilt, as indicated by the diminishing distance between isobases in passing northward. It is likely that there is some irregularity in the height of the summit features due to local warping, but this is probably less than the variation in height of the shore features due to the variable factors in their production. Shore line features found much above the profile given in Plate II may belong to glacial waters, specially if in a side valley or embayment. When evidences of standing waters are found much below this profile then search should be carefully made for higher records. But it needs to be emphasized that local absence of shore line features is very common, and such absence or negation has no weight as against positive occurrence of shore phenomena in adjacent districts. Long stretches of shore line may yield very faint evidence or none at all.

PHENOMENA OF THE SUMMIT LEVEL.

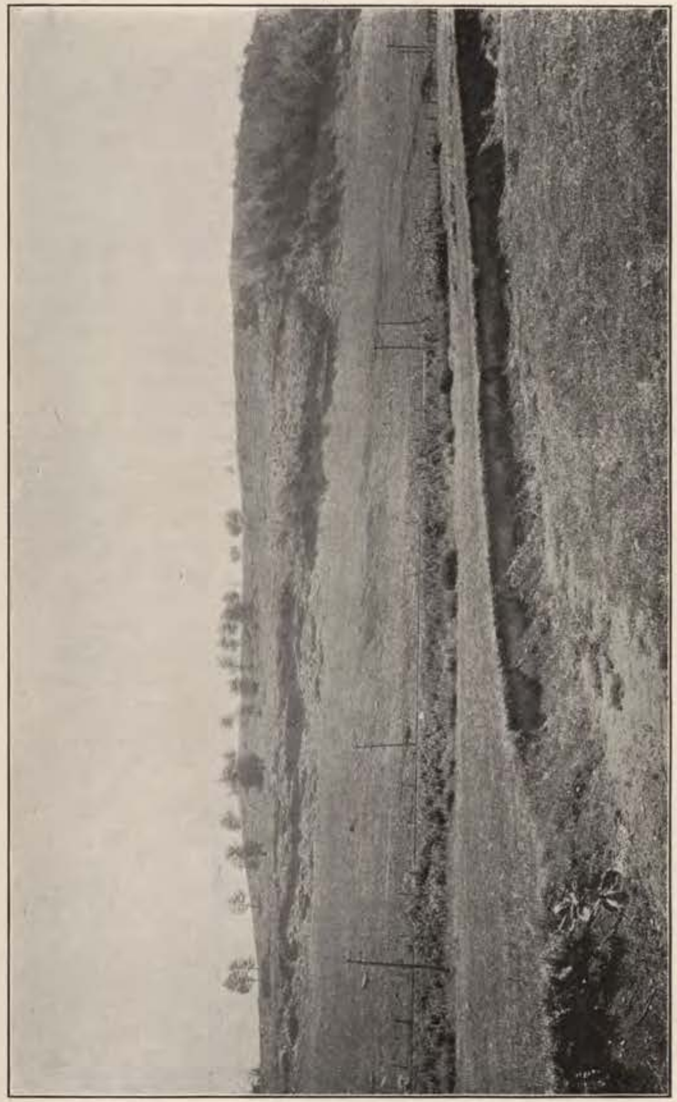
The features which mark the highest stand of the waters are the ordinary shore line phenomena, beaches, deltas and wave-eroded cliffs. Gravel embankments or bars and erosion cliffs are the positive evidence of wave work, but they are not always present because in some sections of the valley, having sufficient width for effective wavework, the marginal waters were either too shallow or too secluded. However, close examination of the valley sides at the theoretic height will usually discover some mark of waves or standing water. It needs to be emphasized that absence of shore phenomena at any locality, or even along a stretch of shore line, is not conclusive negative evidence. Shore features are capricious and often lacking where confidently expected, and where the stand of water is demonstrated by good features on both sides of the negative locality. On the other hand, strong features may be found where not anticipated.

As the land was slowly lifted out of the standing waters, shore features were formed at all altitudes inferior to the summit or initial water level, and often in greater strength. Hence it is not safe to take the highest well-marked features in isolated localities as marking the summit. Only by correlation along considerable distance of shore line can the true summit plane be confidently predicated.

There are several reasons for the weakness of the summit features. The waters slowly fell away from the initial plane, due to the rising of the land. Except in the most favorable places, in exposure and in abundance of coarse material, time was not allowed for the cutting of cliffs or the building of bars. The amount of detritus in the grasp of the earliest water was chiefly that contributed by inflowing streams and the glacial outwash. At lower stands of the water detritus was accumulated by the rinsing down of the upper slopes.

It should be understood that the earliest waters flooded all the valleys of Vermont to a height correlating with the water in the open Champlain and Connecticut valleys and the evidence of the highest water will be found far up the larger tributary valleys. The heavy streams now tributary to Lake Champlain were, during the postglacial submergence, represented by deep estuaries or inlets, and the deposits or deltas of the flowing streams lie far inland, far east of the Champlain valley. The delta of the Winooski lies east of Montpelier, and that of the Lamoille at Hardwick, with tributary filling at Morrisville.

PLATE III.



H. L. F. photo.

WAVE WORK ON ROCK SLOPE.

Two miles south of St. Albans. Looking southeast from highway.

All the streams flowing east or southeast into the Connecticut valley have their summit sea level deltas (sand plains) far upstream and at elevations approximately indicated by the isobasal lines as shown in the map, Plate I.

The most easily recognized proofs of the highlevel waters, and perhaps the most frequent in Vermont, are the deltas or sand plains left hung up on the valley sides. They will be described later in this paper.

Probably the chief reason why the marine submergence has not been recognized has been the failure to correlate or trace in continuity the shore features, and especially the summit features. Some of the latter have been noted in a detached way, and either passed over as a puzzle or attributed to some glacial water marginal to the ice. The beaches and sand plains which have been recognized as made in open static water have usually been features of inferior levels. The weak and detached summit features have been overlooked or ignored. It has been the frequent mistake, in the study of waterlevels, to regard the highest broad and conspicuous plain as representing the highest level of the water surface. Such might be true of a water body with its original level stationary for a long time, but it was rarely the case with the sea level waters, out of which the land soon lifted. The inscriptions of the initial or highest waterlevel are more often weak, fragmentary and inconspicuous. The strong terraces commonly represent inferior levels.

DESCRIPTION OF THE MARINE FEATURES.

PLAINS IN THE OPEN VALLEY.

In the Champlain valley in the northwest part of Vermont two classes of land features are prominent, the extended plains of clay and sand and the bare rock slopes and rock knobs.

The extensive level stretches of clay or sand are very conspicuous and have always been recognized as the product of standing water. The lowest plains border the present lake, while others rise slowly inland. Sometimes the rise is by imperceptible gradation but more often by decided steps, five, ten or twenty feet high. The more extended and very conspicuous plains are associated with the heavy streams now tributary to the lake, as Otter Creek, Winooski, Lamoille and Missisquoi rivers, and have been correctly interpreted as the deltas of those rivers.

The causal relation to the lake of the lowest terraces is evident. But what about the sand plains several hundred feet above the lake and far away, for example those in Essex and east of Montpelier? A little thinking will develop the fact that the material of the high plains was dropped in quiet water, either by the main river or by tributary streams and land wash, all of which implies that a water body must sometime have filled the valley to the height of the highest terrace.

The alluvial plains and delta terraces occur at all levels from the present lake, altitude 95 feet, up to the heights indicated by the marine plane in Plates I and II. These heights are approximately 500 feet at Poultney, toward 600 at Middlebury, about 675 at Burlington, 740 at St. Albans, and over 800 feet on Lake Memphremagog.

The broader stretches of the delta plains usually lie east of the mountain front, but the highest or summit terraces of the larger rivers must be found far up stream in the larger valleys. For example, the earliest or initial delta of the Winooski River is at East Montpelier, and that of the Lamoille is at Wolcott and Morrisville.

Sand plains or other proof of standing water will be found in many valleys of Vermont much above the marine summit plane. Such features were made in local glacial lakes which occupied the valleys when the waning ice sheet blocked the lower (northern or western) ends of the valleys, and held up the waters to some point of outflow, southern or eastern. The highest of the glacial lake features should correlate with the altitude of the lowest point of escape for the waters. Some of the glacial lakes have been described by Merwin (see No. 28 of the bibliographic list) and Hitchcock (7) has noted some of the lower passes which provided outflow for the glacial waters of the larger valleys. Extended discussion of the glacial waters is foreign to the purpose of this report, but will be briefly given in a later chapter.

The shore features will not indicate the old water surface with precision. In other words, we must not expect to determine the height of the ancient water levels to a foot. The levels of the waters varied with storm and wind direction. The level was slowly lowering, relative to the land. And the shore features were not precise in relation to the surface of the water in which they were built. Gravel bars are usually the most definite in relation to the water surface. If the bar is coarse material or cobble the crest of the embankment was probably a few feet, one to five, over the average of the quiet water, being piled by the highest or storm waters. If the locality was sheltered from heavy storm waves and the bar is ordinary gravel it may be taken as the approximate water level. If the bar is fine gravel or sand it may have been some feet beneath the surface. On shores exposed to very heavy waves bars of fine material may be developed off-shore, to a depth of perhaps 15 feet in the Champlain Sea. But if the bar is smooth and flat and of fine material some higher or summit bar will usually be found. It is our practice to take for altitude record the crest of the summit bars. When compared through long distances the error due to variation of the individual bars is relatively small or negligible.

PLATE IV.

H. L. F. photo.

ERODED CLAY PLAINS.

Five miles southeast of Hinesburg. Looking northwest. The most common feature of the lower levels.

Sand plains and delta terraces are not so accurate criteria as the gravel bars. They may vary from some height above the water plane to perhaps 20 feet below. There are several factors involved in this variation relative to the water surface. These are the volume and velocity of the stream; the amount of its detritus; the character of the detritus; the depth and capacity of the receiving basin; the exposure to strong waves and shore currents. Without extended discussion of these variable factors and their complex effects it may be simply stated as follows: A stream with a heavy load of detritus, and specially of coarse material, is likely to build the head of its delta, or apex of the deposit, above the level of the receiving water. This is more likely when the standing water is sheltered from heavy waves and strong shore currents. The deltas of streams in the deeper valleys may be many miles inland, and the heads or apexes of the deltas may be built up, or graded, far above the marine plane, perhaps 20, 30, or even 40 feet. On the other hand if the detrital load of the stream is small, relative to the volume of the stream, or the material is fine and easily drifted, or the standing waters have breadth and effective movement, the summit plane of the delta may be entirely beneath the water surface. In light of these facts it will be understood that there may be considerable variation in the height of sand plains or deltas at different localities yet built at the same time in the same water body. In figuring the altitude of waterlevel from the summit plains of deltas it is desirable to average many occurrences ranging through considerable distance of shoreline.

Wave cut cliffs may give approximate height of the water surface, which lay above the sharpest concavity at the cliff base, and up on the steep face of the slope. But in Vermont the rocks that were exposed to wave erosion at the highest level of the waters are so hard and resistent that time was not allowed for carving distinct sea cliffs.

RINSED ROCK HILLS.

A feature not so obvious to the traveller or casual observer as the wide plains, but which appeals strongly to the critical student, is the washed-off or rinsed-down appearance of the steep slopes and rock prominences in many localities. This feature is most striking in the northwest part of the State where the hard crystalline rocks lay more widely within the reach of the early marine waters. It is a character that should be expected where wave action of standing water has had opportunity to sweep the glacial drift from exposed points. But as this phenomenon reaches far above the conspicuous plains and where other shore features are rare or weak, they have not been recognized as an effect of the same waters as those which produced the broad sand or clay plains.

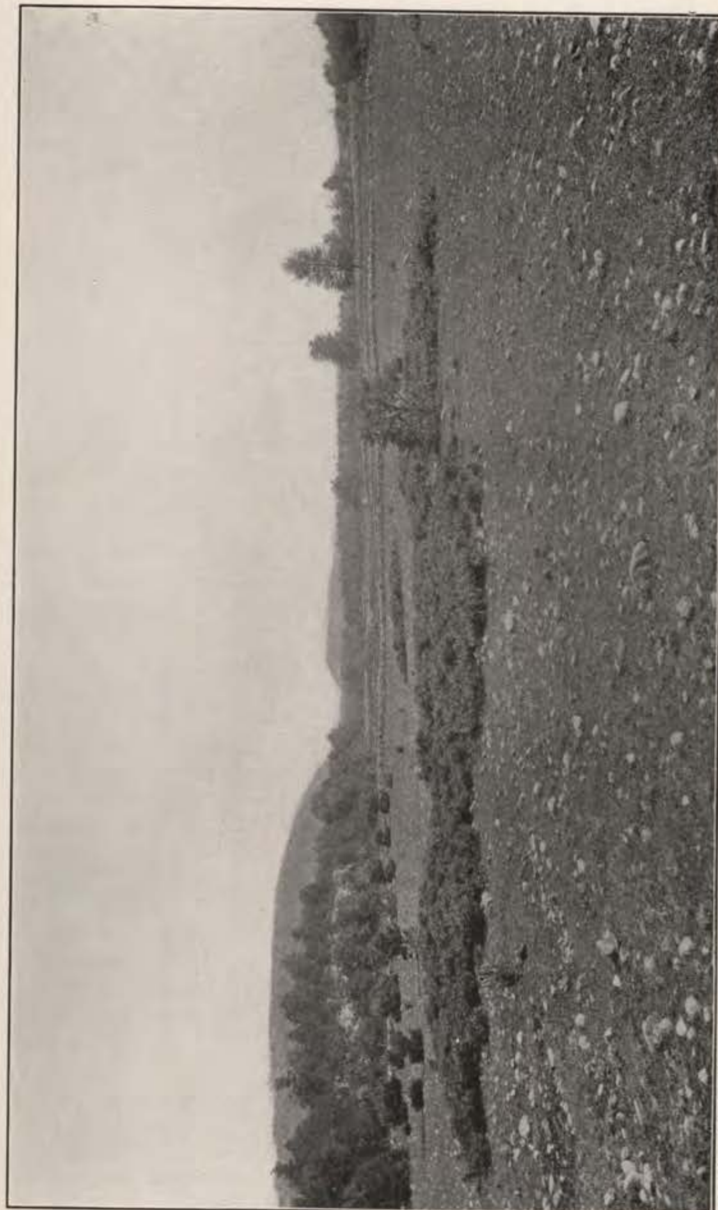
The bare rock knobs were rubbed by the glaciers and the dome shape or smooth convexity, specially on the north side, and the polished surfaces are the effects of glaciation. But the fact that so many knobs and slopes are destitute of any drift or soil cannot be wholly explained by the action of rain and wind. This nakedness is partly the erosional effect of the marine waters which accumulated the sand plains as a constructional effect. The bare rock knobs may be frequently correlated in altitude with recognized shore features. A rinsing process has affected all the ridges and knolls up to the highest plane of the sea level waters. Of course the pinnacles of rock and steep slopes have been eroded by rain and wind at all altitudes. But some difference may be noted in the character of the slopes above the summit marine plane and below it. Where the clearing is due to storm-wash the finer materials would be the more easily removed, and this would accumulate irregularly at the bases of the cliffs and ledges. The coarse materials, the blocks and well-anchored stones, might be left in place, while the medium coarse would accumulate at the foot of the steep slope, to form a talus or a series of detrital cones. The effect of storm-wash is to roughen the slopes and to produce vertical furrows or channels in slopes of weak materials. On the contrary the wave-washed slopes are swept clean of both coarse and fine materials, the light and heavy together, and the slopes are given a horizontal allineation, instead of the vertical, as by rain-wash. The detritus at the foot of wave eroded slopes has a smoothed-out, horizontal surface very unlike the talus accumulation by rain and weathering.

The waning ice sheet dropped its burden of rock-rubbish over all the land surface. But very little drift is now found on the rock slopes that have been exposed to wave-work, even up to the highest plane of the marine waters. Not even large blocks or erratics are found. The writer has noted only one conspicuous perched bowlder. The waves swept the loose blocks from their moorings and tumbled them down the slopes, and often buried them in finer stuff. Plate III is an illustration of these features, which may be found in abundance.

In places, specially at lower levels, it appears that a group of stone blocks has checked the wave action and acted as a break-water and the fine detritus is spread around the blocks in smooth, horizontal surface. This is a peculiar wave effect which rain or storm-wash can not produce.

In general it may be said that knobs and ledges and steep slopes have been brushed clean, while hollows and depressions have been more or less filled and smoothed. All the land surfaces in the drowned area have a peculiar washed-off and filled-up appearance. And this has been produced so recently that modern weathering has not greatly affected the exposed rocks, nor seriously gullied many slopes, except by definite streams. Lo-

PLATE V.



H. L. F. photo.

SALISBURY COBBLE PLAIN.

One and one-half miles south of East Middlebury. Delta of glacial flow of Middlebury river. Altitude 580 feet. Looking south from farm road.

calities may be specified for study of this character, as follows: south of St. Albans; south from Burlington along the Rutland Railroad; northeast of Middlebury; east and northeast of Brandon; about Hydeville and Castleton, and south to Poultney. On any of the railroads west of the mountain front the traveller may see, looking toward the higher ground, these characteristic features of wave-work. In the Connecticut valley, with its narrow waters and weak wave action, these features are not conspicuous.

SHORE LINE FEATURES.

Deltas and Terraces. The most conspicuous plains are the lower terraces of the larger river deltas. But the small deltas of the minor streams are of equal geologic importance and really more interesting and convincing to the observer in the field. The very small deltas of mere brooks, built in quiet or sheltered waters are the best indication of the precise elevation of the standing water surface.

In the Champlain basin deltas are found on all the streams which flow westward, emerging from the mountain front. Examples are at Forestdale, three miles northeast of Brandon, where Mill River reached the sea level waters; at East Middlebury, on the Middlebury River; at Bristol, the village standing on a beautiful delta of New Haven River. Strong deltas lie south of Hinesburg, showing clearly on the Burlington sheet of the U. S. topographic maps. Many other deltas may be found where any streams poured down from the highlands into the standing waters. It has already been stated that the heavy summit delta of the Winooski is at East Montpelier, and that of the Lamoille at Morrisville.

In the Connecticut valley the deltas of the lateral streams are well developed. The west slope is fairly uniform, with many streams of rather steep slope pouring into the landlocked and quiet waters. It is not desirable to attempt any detailed description of the Connecticut valley deltas in this report. The student of this subject should look for the deltas upstream and at elevations somewhat above the theoretic marine plane as shown in Plates I and II.

The succession of terraces on the deltas, with rather steep, bold fronts is the effect of the falling waterlevel, relative to the land.

The altitudes of the summit deltas will be found in practical accord with the uplifted marine plane, as plotted in the map.

Bars and Spits. The level-crested, smooth and narrow ridges or embankments of cobble, gravel or sand are the clearest evidence of wave-work and current action along a shore line. On the New York side of the broad valley are series of splendid cobble bars, ranging from the summit level down to 100 or more feet below. These occur more commonly on heavy deltas of coarse material. In Vermont these features are not well developed. The important requisite factors are an abundance of cobble or very coarse detritus, and secondly, vigorous wave action. There must have been strong wave and current work along the Vermont shore, on the mountain front facing west, all the way from St. Albans south to beyond Brandon, but there were no extensive delta tracts of coarse material, because the large rivers had left this far inland. (See page 25).

Several streams of the second class, in size, built good deltas, as already noted (page 9). Elegant gravel bars are seen on the Bristol delta, on the south side of the river. Figure 2 is a sketch map of the bars and Plate X is from a photograph of one of the inferior bars. Heavy bars lie on the edges of the terraces of the Hollow Brook delta at South Hinesburg. A good series of strong bars lie on the south point or nose of the hill, two miles south of East Middlebury, on the south side of the road, only 25 feet beneath the theoretic plane.

Conspicuous bars may rarely be found in localities apart from river deltas. A beautiful series of bars occur on the east slope of North hill, two miles northwest of Williston, shown in plate 13. And a series of strong bars on a well-developed shore lie along the east side of the highway two miles southeast of Hinesburg (Plate XII).

Many weak bars occur on the hills north of Brandon, along the middle road toward Leicester village; and also along the north and south roads between Sudbury and Whiting villages. Anyone interested in these phenomena may find many more or less definite bars of gravel at different localities, and they should note them and report to the State Geologist.

Bars and spits (rudimental or unfinished bars) were made at various levels of the subsiding waters. Consequently those found at any single locality can not alone be positively regarded as marking the summit level. Comparison must be made with other features along a far stretch of shore line. The summit features are the most important, as denoting the highest stand of the marine waters, or more correctly, the greatest depression of the land.

It is well to keep the fact in mind that the entire absence of any visible shore phenomena at any point, even where they should be expected, below the summit plane, is no proof of the non-existence of the standing waters.

Wave-cut Cliffs. These features are not common nor conspicuous in Vermont, for two reasons: first, the hardness of the rocks in the marine flooded area and its resistance to erosion, and second, the lack of permanence of waterlevels, because the land was rising out of the sea.

Many rock faces are found with smooth sand fields at the bases. Such rock cliffs are not erosional, except to the degree

PLATE VI.

H. L. F. photo.

COBBLESTONE FENCE ON SALISBURY PLAIN.
Looking west from near house of William Prieur. See plate 5.

that the cliff face has been cleared of the drift or soil. Perhaps the rock has been somewhat smoothed by wave action. The terrace below is depositional or constructional.

The most positive erosion cliffs and clearest to the view are those on deltas, where they form the steep, bold fronts of the terraces. Excellent examples are seen on the South Hinesburg delta, shown in Plate XI.

AREAL DESCRIPTION.

CHAMPLAIN-ST. LAWRENCE AREA.

The purpose of this chapter is to give more detailed, local description of, or at least direct attention to, the group of features in the several districts lying within the territory inundated by the marine-level waters. This is with the desire to interest the people in the remarkable objects and the dramatic history of their home localities.

The southern part of the State, below Poultney was above the sea level, and does not come into our story. The ocean level waters first invaded Vermont at Poultney and Fair Haven, extending inland to the Rutlands. The topography and history of this district is the most complicated and difficult to unravel and describe of any part of the State. For that reason it is unfortunate to make it the first of the list. But as the sea level waters invaded the State from south to north, as the ice front receded, the chronologic order in the production of the phenomena seems the proper order for this description.

POULTNEY-FAIR HAVEN-CASTLETON DISTRICT.

The reader should have before him for the clearer understanding of this discussion the Castleton and Whitehall sheets of the topographic maps (see footnote, page 3). The two sheets on the south, Fort Ann and Pawlet will be helpful.

Judging from the topography and the position of the valleys the first sea level waters to reach Vermont probably entered through the Mattewee valley in New York (Fort Ann quadrangle), and covered the site of Poultney and East Poultney villages. There may have been a small invasion through Granville, N. Y., toward North Pawlet and Wells villages. At a little later time with a few miles of ice-front recession the waters reached in to Fair Haven and Poultney by the low pass between Fair Haven and Whitehall, now utilized by the Delaware and Hudson R. R.

The theoretic marine plane is about 500 feet altitude at East Poultney, and about 510 feet at Fair Haven. Poultney and East Poultney villages are located on the summit delta built by the Poultney river in the earliest and highest marine waters. The altitude of the Poultney sand plain is from 420 to 460 feet, and it rises by steps to the summit terrace at East Poultney five-corners with 540 feet altitude. This is seen very clearly in passing along the highway between the villages. And the upper limit of the detrital filling is well shown.

The delta summit at East Poultney is 40 feet above the theoretic, uplifted sea plane, as shown in Plate II. It is certain that the Poultney river, with its heavy load of detritus, built the head of the delta much above the level of the standing water. This is a good example of a heavy delta filling in a secluded or shut-in valley. It is possible that some allowance should be made for the gravitational pull of the ice body, combined with that of the high hills about the valley, in attracting and raising the marginal waters somewhat above the general sea level, but this is indeterminate. In some cases of discrepancy of levels it is possible that land warping or excessive local uplift or lack of uplift may be a true explanation; but it is not seriously considered in this writing. The delta filling at East Poultney truly represents at some line on its surface the early sea level water plane. No bars have been noted, and wave action was weak in the secluded, narrow valley.

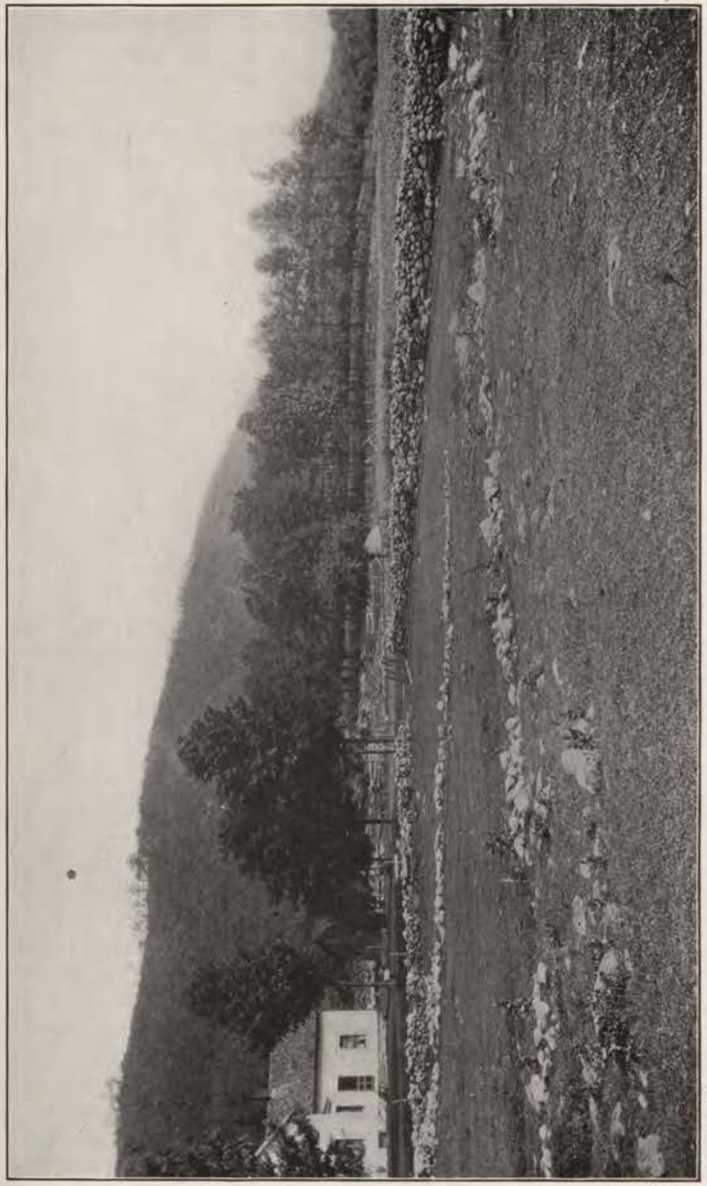
At Fair Haven the extensive sand plains are much below the summit level. The plain on the north side of the Castleton river, under the main village, has altitude of 400 feet, while the south plain is only 380 feet. This low altitude is to be expected, since both the Poultney and Castleton rivers built their summit deltas of the coarse material far up stream, and the amount of detritus contributed by the weak local indrainage was insufficient to fill the valley. The deposit was levelled during a lowering stage of the water.

North of Fair Haven is an unfilled lower valley of 360 feet altitude, which clearly proves that the material of the Fair Haven plain was not derived from the north, or from glacial outwash.

The traveller on the Electric R. R. between Fair Haven and Castleton cannot fail to notice the unusual sand plain terrace that carries the highway from Hydeville to beyond Castleton Corners. The topography is clearly indicated on the Castleton sheet. This plain is 360 feet in height. Similar plains occur across the valley on the south, at the same or lower levels.

It is possible that the valley between Hydeville and Blissville was filled clear across at above what is now 400 feet, and that the river has eroded the broad, low valley east of Hydeville out of its earlier deposits. Toward Castleton the ancient valley was certainly filled up to the present 440 feet. South of Castleton and east of Parker Hill the broad sand plain, on which the highway lies, has altitude of 500 feet, which is only 20 feet beneath the theoretic waterlevel. All the depressions in this district, including that which holds Lake Bomoseen, were flooded by the marine inva-

PLATE VII.



H. L. F. photo.

GLACIAL RIVER CHANNEL WEST OF BRYANT MOUNTAIN.

Two miles south of East Middlebury. House of C. W. Evarts. An earlier and higher flow than that which made Salisbury cobble plain. Looking downstream.

sion, and the smooth stretches of sand and clay between the hills, at various levels up to 500 feet, are the witnesses.

Two episodes in the history are clearly recorded in the present land forms and materials. First, a time of standing water at high levels, in which the stratified detrital deposits were built and leveled; and second, the erosion of the deposits by the present streams and production of the present topography as the region was slowly lifted out of the standing waters.

Rutland District.

The Castleton and Rutland sheets are necessary, and the Pawlet and Wallingford sheets are desirable.

In the district we have some peculiar geography, a remarkable relation of the ancient, preglacial valleys, and contrary directions of the present drainage. We have three parallel north and south valleys, with a narrow intercepting east-west valley, the Castleton river channel.

Rutland city lies in the north end of the eastern valley (Clarendon-Wallingford), which is drained northward by Otter Creek. Center Rutland lies in the south end of the middle valley (Pittsford-Proctor), and this valley carries the continued northward flow of Otter Creek. West Rutland is situated in the southern part of the western valley, which slopes south and is drained south and then west by the Castleton river.

The theoretic marine plane has altitude at Rutland city of about 525 feet. The sand plain on which stands the lower and level part of the city is 530 to 540 feet. The valley bottoms at Center Rutland and West Rutland are flat silt plains at 500 feet. The head of the narrow Castleton channel, for two miles is 500 feet. South of Rutland city the broad Clarendon valley for six miles has its bottom plain 540 feet. This valley appears to have been the catchment basin for the Otter Creek delta in the sea level waters. The detrital plains in the several connected valleys strongly suggest control by the marine waters. And this is probably true. But there are some complicating factors. It appears that Otter Creek has at Proctor a rock barrier and dam at 480 feet, which suggests that the silt plains at 500 feet might be the flood plains of the present streams. However, the Clarendon sand plains at 540 feet are independent of this stream control.

Further complication is found when it appears that heavy sand plains occur in these valleys at altitudes decidedly above the marine plane. Examples will be noted below. We certainly have to recognize the presence of glacial waters in these valleys previous to the sea level waters. There was a time after the valleys in the Rutland district were relieved of the ice, and were open as today, that the ice front still lay over the ground on the north and west so as to block any drainage in those directions. Then the lowest escape was southward at the head of the Otter

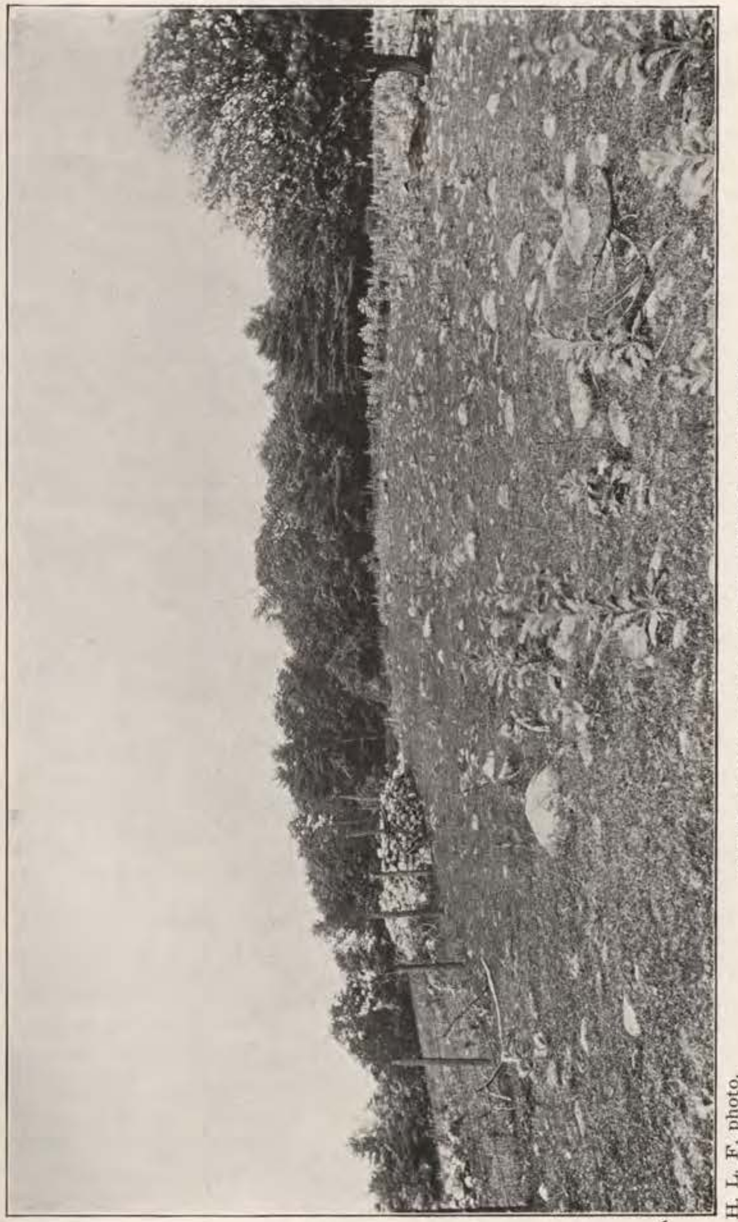
Creek valley, near East Dorset, utilized by the Bennington & Rutland Railway. The height of that pass today is 788, or about 800 feet for the river surface. A glacial lake existed for a time, to be counted in centuries at least, in the Wallingford-Clarendon-Rutland valley, with its outlet at East Dorset and its uplifted plane today grading from 800 feet at the outlet to about 850 feet at Clarendon, 860 at North Clarendon, 865 feet at Rutland and still higher northward. Deltas built by streams pouring into the lake, which we may name the Wallingford lake, indicate the old water surface. Two of these highlevel deltas have been examined. One is the extensive plain at East Clarendon, built by the Mill river. On the north side of the stream the summit terrace carries the cemetery, schoolhouse and Adventist church, having altitude of 825 feet. On the south side a mesa-like plain appears to be 20 or 30 feet higher or about 845 to 855 feet. This point is 20 miles north of the East Dorset outlet, and with differential uplift of 2.5 feet per mile, the theoretic water plane is about 850 feet. A lower terrace of the East Clarendon delta is the Butler Brothers' farm, with altitude of 780 down to 700 feet.

The other delta is that of Cold river, a mile east of North Clarendon. The sand plain is here mainly on the south side of the stream and is 780 to 880 feet altitude. A highway traverses the delta, on which is the farm of H. K. White.

There doubtless came a time when the ice blockade was lifted from the Castleton valley, but yet lay across the land on the north. During this episode the escape for the glacial waters was by the Castleton channel, west of West Rutland. It is probable that somewhere between West Rutland and Castleton the narrow valley was partly filled with rock-rubbish from the ice sheet (glacial drift), and for some time this drift barrier held the waters in the Rutland district much above the marine plane. The river flow eroded the barrier and slowly lowered the outlet. The clearing out of the channel was probably aided by the copious flood from the melting ice on the north. If this be a true history then we should expect to find stream deltas along the sides of the valley at various altitudes lower than the Wallingford lake plane and above the marine plane. And that is what we do find. Some of the well-marked, elevated shore features are as follows:

Terraces occur a mile south of West Rutland at 560 feet, or about 40 feet high, in comparison with the marine plane. An excellent delta of Sugar Hollow brook north and northeast of Pittsford with the summit at 620 feet, or 70 feet high; a good sand plain one and one-half miles southeast of Rutland city at 600 feet, or 80 feet high; an extensive delta of Cold river at North Clarendon with terraces from 560 up to 660 feet, or 40 to 140 feet high. At Clarendon the delta of Mill river shows terraces from 560 to 630 feet, or 50 to 120 feet high. The student of this subject will find many other evidences of high water.

PLATE VIII.



H. L. F. photo.

WEST BANK OF GLACIAL RIVER CHANNEL.

The channel is shown in Plate VII. Looking northward. Edge of ice sheet lay against the left hand slope.

These deltas and their levels are too diverse in vertical altitude to represent a single or permanent waterlevel. They indicate a falling level of the standing water, and the only pass which meets the conditions is the Castleton valley. Eventually the drift blockade was swept out of the valley, going to help build the sand plains at and below Castleton, and the waters of the Rutland lake were lowered to the sea level. The alluvial valley bottoms in the Rutland district are 20 feet below the marine plane. West Rutland is on the divide between the Otter and Castleton drainage, and probably represents the bottom, or the depth, of the river which carried westward into the sea level waters the copious flood of all the Rutland drainage area. The sand plains at about 540 feet at Rutland and south toward Clarendon represent the marine stage.

Brandon District.

The Brandon topographic sheet covers the territory.

The district about Brandon and Forestdale is rich in phenomena produced by the marine flooding. The theoretic plane is about 555 at Brandon and 560 feet at Forestdale. At the latter village is found the most extensive delta in the region, that of Mill river. The marine level is seen in the extensive lower plain, west of the village, by the mills. This level is backed by a steep erosion cliff. At Brandon the true plane is best seen along the north and south road one and one-half miles east of the village, where small streams brought detritus down the mountain front.

The village of Forestdale is on the delta tract which lies somewhat above the true plane, from 580 to 600 feet, and possibly higher. This elevated portion probably was built in the lower stage of the glacial Rutland lake, already described.

The greater number of beaches, terraces and cliffs in the district are beneath the summit sea level, and represent the subsiding waters. Brandon village is on a sand plain at 440 to 460 feet, or a hundred feet below the highest marine level. Many gravel bars, of weak character, may be seen along the east road leading north to Leicester corners, at altitudes of 500 to 525 feet. Another district with many bar features is between Whiting and Sudbury villages, with altitudes of 520 down to 400 feet or less. None of these embankments are strong or conspicuous, but their abundance, in different localities, with corresponding height, makes them good evidence of broad standing waters.

Delta terraces of inferior levels have been noted on the Crown Point road, on the west side of Otter creek valley; also three miles southwest of Brandon. Delta phenomena should be found wherever streams swept detritus down from high ground.

Middlebury District.

The Middlebury and Brandon sheets are requisite.

The long stretch of shore line lying against the bold, steep, west face of the Green Mountains, and extending in nearly a direct line from South Hinesburg south to beyond Brandon is a very interesting and important section for our study. Along most of this mountain front the waves at the summit and higher levels spent their force against the bare rock slopes, and have left slight evidence of their work. But there is striking proof of the high level waters in the deltas, built where streams laden with detritus debouched into the standing waters; as well as some strong beaches in a few localities.

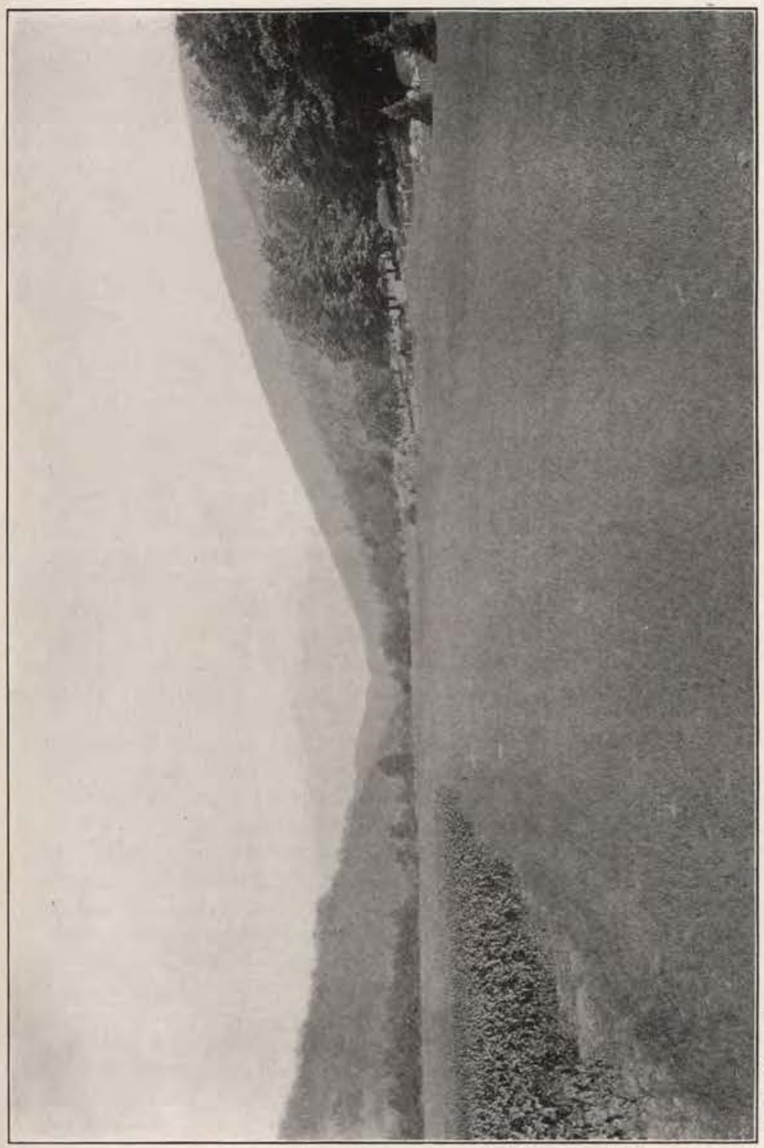
This district was not, like that of Rutland, in the field of any large glacial lake, but does include fine examples of river channels cut by glacial or ice-border drainage.

Lake Dunmore occupies a basin produced, probably, by the damming of a preglacial valley. The dam is the delta plain at the north end of the lake, between Sunset Hill and Bryant Mountain. This sand plain was the delta of a glacial river built in the sea level waters. When the ice front lay against the west face of Bryant Mountain the flow of Middlebury river was compelled to pass southward along the ice margin. The well-marked channel of the ice-bordered river is followed for a mile by the highway from the forks in the road southward toward the lake. The sand plain about the north end of the lake is the delta of the Middlebury glacial river. Near the lower road forks is a rough, bowldery ground which would be mistaken for moraine, but which is the very coarse detritus left by the torrential flow of the glacial stream (see Plates 7, 8). Farther north by the highway along Pine Hill and west of the highway is the channel of the upper part of the glacial river as it emerged from the Ripton valley.

The features just described, with the events they indicate, suggest what happened at various localities along the steep mountain face. The abandoned channels of glacial stream flow may be seen at many points and at different altitudes above the marine level. They should be observed on the highways leading eastward up the highlands. Such channels in the Brandon district have already been noted.

The most interesting glacial delta in the district is connected with the glacial flow described above. This is the great cobble plain known locally as "Salisbury Plain," lying between Bryant Mountain and Brush Hill south of East Middlebury. When the ice front weakened at this point the marine waters entered the hollow between the two hills, and the glacial river dropped its heavy detritus here instead of at the head of the Lake Dunmore valley. Plate V is a view looking south across the cobble plain. The altitude is 580 feet, while the theoretic marine plane is 585

PLATE IX.



H. L. F. photo.

PLAIN ON BRISTOL DELTA.

South side of New Haven River. Looking east. Altitude 580, and 15 feet below the bars shown in Figure 2. See Plate X.

feet. Along the west side of the plain and at the foot of the hill is a definite channel or hollow, which probably was produced by the latest outflow of the glacial waters. At the north end of this channel are higher stream cuttings, under the road and against the morainic knoll. At the south end is the dump or submerged delta of this latest flow. This forms the nose of the hill, south of the road, and the lowering waters shaped the fine gravel into a series of handsome bars, mapped in figure 1.

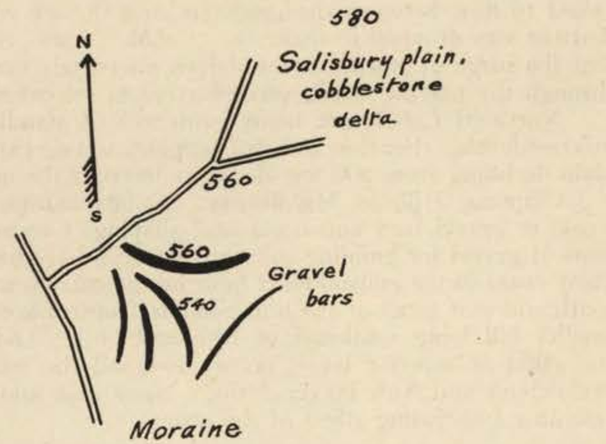


FIGURE 1. Gravel bars south of Salisbury Plain.

East Middlebury village stands on the remnants of the delta when the Middlebury river freely entered the sea level waters at that place. The sand plains on both sides of the river are only remnants of the original delta, as the modern river has cut away much of the original deposit. The theoretic level is here about 590 feet, while the highest gravel knoll, north of the village, is only 540 feet. The low plain on which the village stands, with height 440 rising to 520 feet, appears to be a recent floodplain of the river. A feature which marks the summit level of the waters is a terrace east of the village, by the sharp bend in the road on the north side of the river, at altitude 585 feet. Above this is morainal drift. Glacial stream work is found above the terrace, on the road, as a definite channel and a higher shelf.

The writer has not explored the ground past Dow Pond for five miles north of East Middlebury, but some interesting features will be found in that stretch. At the locality named "Cobble" on the map, five miles northeast of Middlebury, is another singular plain of cobble and coarse gravel. It fills a space about one-third mile in breadth between the steep front of the mountain and the south point of a rock hill. Its altitude is 580 to 600 feet, while the marine altitude is 600 feet. It is a plateau, with the ground declining away from plain both north and south.

The map does not indicate any association of this cobble plain with any present stream. It is probably a glacial stream delta, similar to the "Salisbury Plains" delta. When the ice front lay against the mountain face two miles southeast of New Haven Mills the waters from the melting ice and the land drainage from the depression in which runs the "Little Notch Road" was compelled to flow between the mountain and the ice edge, and the detritus was dropped to make the "Cobble" delta. It is possible that the surge of storm waters, driven alternately north or south through the narrow strait, was effective in smoothing the plain.

North of Cobble are many evidences of standing water at inferior levels. Beaches and cliffs appear, and an extensive sandplain declining from 500 feet down to 380 near the mills.

Chipman Hill, at Middlebury, exhibits conspicuous wavework, in gravel bars and horizontal shaping. Extensive excavations of gravel for building and road material have been made for many years in the embankment built by the marine waters on the south and east faces of the hill. Similar features are seen on the smaller hill lying southeast of Chipman Hill. And bars, spits and cliffs at inferior levels occur along all the roads between Middlebury and New Haven Mills. Many rock knolls show the denuding and rinsing effect of the waters.

Bristol District.

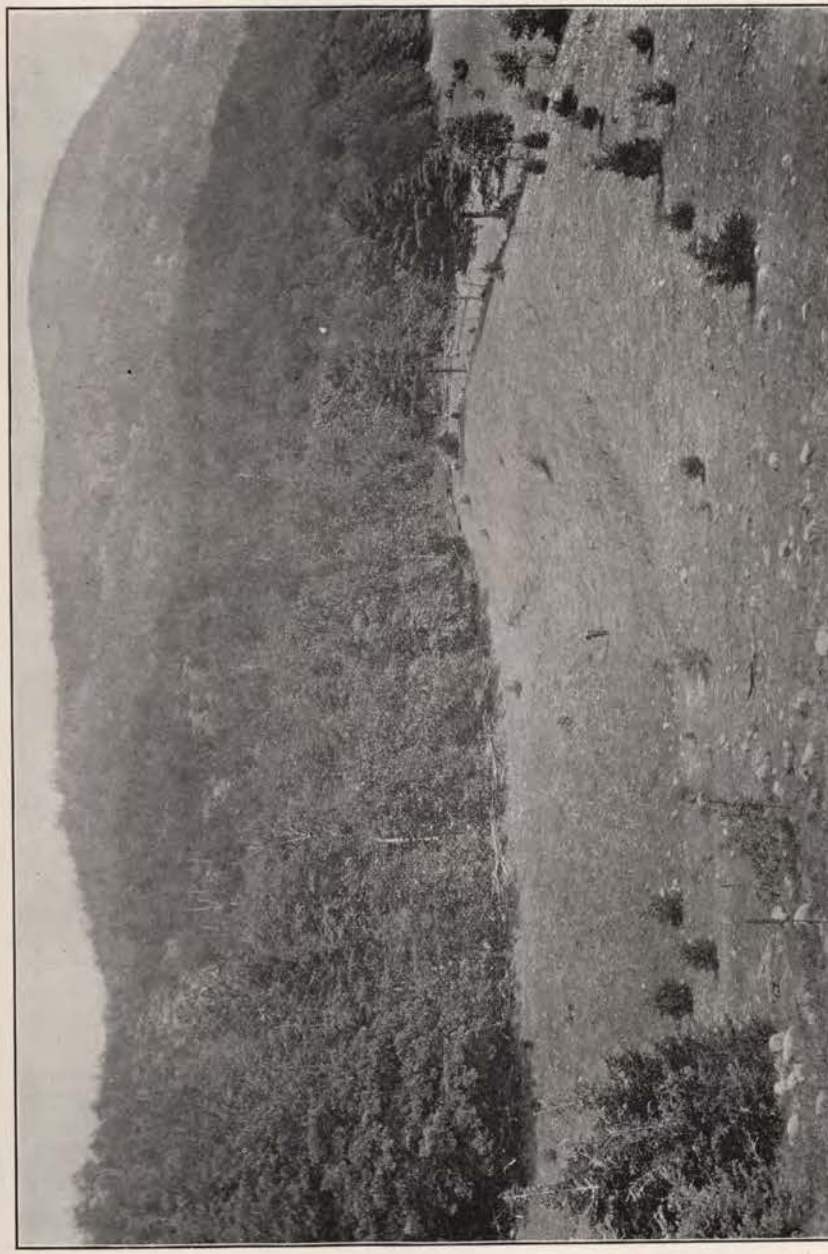
The Middlebury topographic sheet shows all the features in this district.

The village of Bristol stands on the broad delta plain of the New Haven river. A portion of the delta lies across the deep ravine, on the south side of the river, but the two portions were continuous at the time of deposition. With the lowering of the marine waters the river deepened its channel or intrenched itself in its former delta. The east edge of the village, along the north and south road, is on the back edge of the delta, at 620 feet. This is clearly shown by the topographic map, and the height is the precise theoretic altitude of the marine plane at this point.

The "Bristol Flats," south of the village, is the lower and later delta plain of the river, built in the falling waters, with altitude declining from 420 to 340 feet.

The delta remnant on the south side of the ravine carries some handsome bars, which are shown in the sketch, figure 2, and Plates 9, 10. These gravel bars are 25 feet beneath the highest level of the standing waters, the summit bar being taken as 595. A cliff in the forest on the point of the hill shows the latest glacial stream work.

PLATE X.



HEAVY LOWER BAR, BRISTOL DELTA.

H. L. F. photo.

Looking southeast from the summit bar. Altitude 570. The summit bar 595. See Figure 2.

Another interesting locality is the narrow valley lying behind the Hogback Mountain, and now occupied by the Beaver and Baldwin Creeks, flowing south and the Lewis Creek, flowing north. The Beaver-Baldwin has a flat silt-plain bottom which correlates with the marine waters. The marine waters were 620 feet at Bristol. At Ackworth the silt plain is over 600 feet and rises to 665 feet in four miles up the valley to the divide. This slope represents the gradation of the river deposit, adjusted to the several factors, the baselevel (the standing waters); the capacity of the valley; the volume of the stream; the amount and character of the detritus.

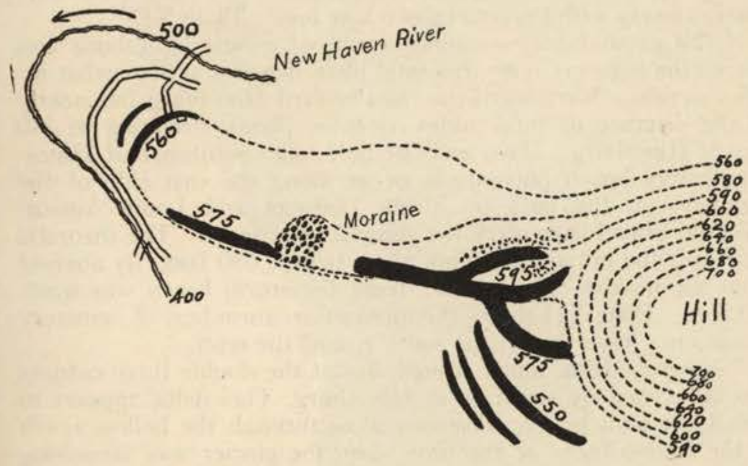


FIGURE 2. Bars on delta at Bristol.

In the valley of Lewis Creek, with northward slope, are some sand plains and terraces above the marine level, the stronger being a mile south of Starksboro, with altitude about 670 feet. The explanation is glacial waters. Here we have such relation of valley and highland as to prove very clearly a necessity for a glacial lake. When the ice front lay against the north end of Hogback Mountain it was a barrier across the north end of the Starksboro valley. The Starksboro glacial lake was held up to the height of its outflow, across the divide at the head of Lewis Creek, which is 665 feet. This outlet determined the level of the ice-dammed waters certainly as far north as Rockville and possibly to South Hinesburg. Examination of the region about Starksboro and Rockville will find many proofs of quiet water standing at 660 to 680 feet.

Hinesburg District.

This region is covered by the Burlington sheet.

The delta of Hollow Brook, at South Hinesburg, has the boldest terraces and strongest vertical relief of any delta seen by the writer. The reader who wishes to see with his own eyes an ancient or "fossil" delta built in the sea level waters when the district was 650 feet lower than at present cannot do better than pay this locality a visit. The flat terraces with bold, steep fronts and heavy gravel bars on the edges are impressive. The higher terrace, contoured on the Burlington sheet at 660 feet was probably built in the Starksboro glacial lake. The lower terrace, contoured at 620 feet is certainly marine. A storm beach at the rear of the higher delta terrace has altitude about 670 feet, which correlates closely with the Starksboro lake level. Plate XI.

The ground for two miles south of South Hinesburg and east of the highway is eroded sand plain deposits at somewhat inferior levels. Northward the road toward Hinesburg lies nearly all the distance of three miles on these plains, declining to 340 feet at Hinesburg. Two and one-half miles southeast of Hinesburg heavy beach phenomena occur along the east side of the highway, on the land of Frank Bissonet and Louis Amour. Splendid gravel bars mark the summit waterlevel. The theoretic figure for the initial or summit plane is here 650 feet. By aneroid from the nearby corners (531 feet) the storm beach was made 660 feet. Plate XII shows the topmost or storm bar. A cemetery stands on a lower bar at the south end of the tract.

A heavy delta, much eroded, lies at the double three-corners two miles east by south from Hinesburg. This delta appears to have been built by glacial stream flow through the hollow north of the four-corners, at the time when the glacier was depositing the moraine south of Hinesburg lake and northeast of Mechanicsville.

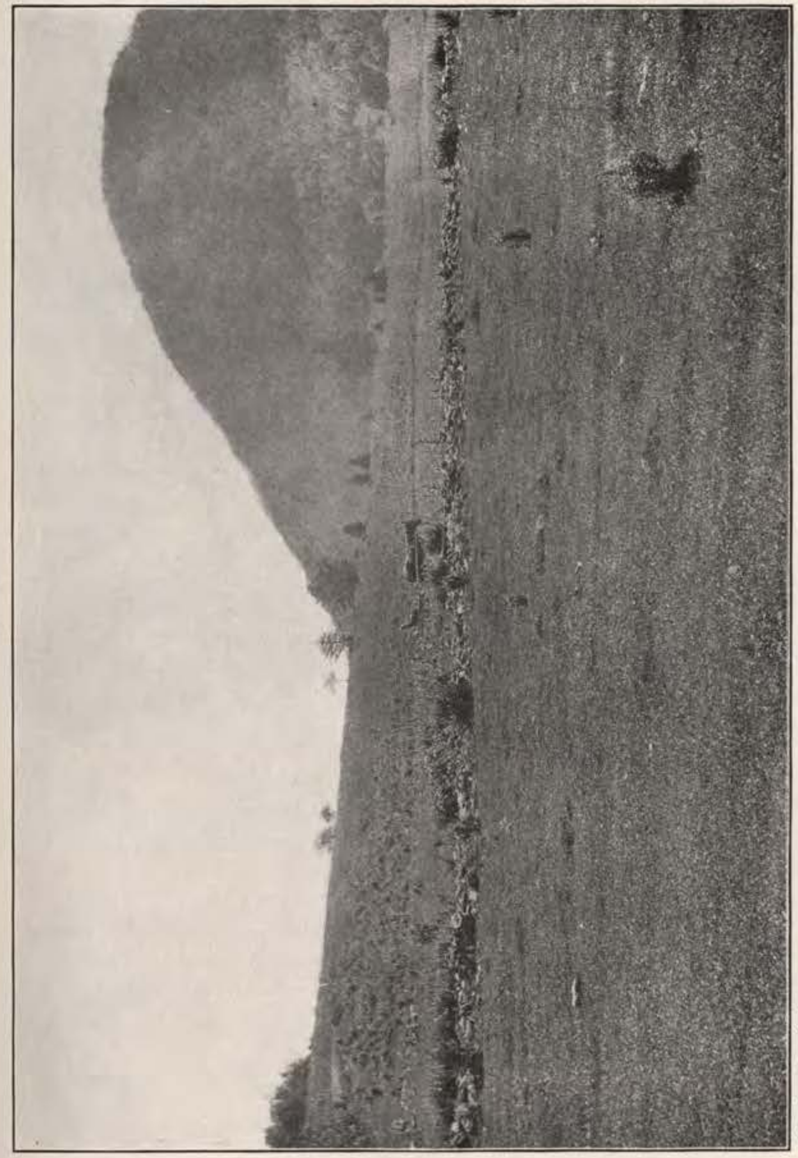
Burlington District.

The Burlington, Milton and Plattsburg sheets are required to cover this territory.

Perhaps the most extensive delta plains in the State, and certainly those most familiar to the people and to travellers, are those in the region of Burlington and the Winooski valley. The topographic sheets clearly show the level terraces by the white areas (lacking contour lines), at all levels from the present Lake Champlain, 95 feet, up to 500 feet. The map contours show broad plains at 100, 200, 300, 320, 400 and 500 feet. The theoretic altitude of the marine plane at Burlington is 675 feet, and perfectly clear evidences of standing water and effective wave-work are found up to this height.

The great delta plains of the Winooski river, covering large areas of the towns Colchester, Burlington, Essex, Williston and

PLATE XI.



H. L. F. photo.

STORM BEACH, SUMMIT OF MARINE PLANE, ON HOLLOW BROOK DELTA.
Looking southeast from the upper delta plain. Altitude 660 feet.

Jericho, and extending up the valley to beyond Montpelier, were built in the open sea level waters of the Champlain valley, and the splendid display of plains and terraces were carved by the combined work of waves and currents as the region was slowly lifted out of those static waters.

The features of the summit level are the important matter, and these have been found at many places. Clear but weak shoreline characters occur three miles southeast of Williston by the three-corners marked as 668 feet. A good terrace and cliff lie some ten feet above the road corners. Passing east gravel banks and silted slopes occur at 675 feet and downward, and are seen for two miles along the road on both sides of the narrow valley. In such protected valleys the static water phenomena, while weak, may be very clear and indicative of the highest water plane. At the three-corners, one-half mile west of Fay's Corners are gravel terraces from 675 feet down to 625.

The best display of gravel bars at the summit and declining levels is on the North Hill two miles northwest of Williston. The top of this hill, 680 feet by the map, is glacial drift. A sloping bar lies near the summit on the southeast side reaching up to 670 or 675 feet. A strong bar-like ridge lies on the southwest side at about 650 feet, with a prominent cliff and terrace below, shown in plate 12. An extensive shelf, apparently due, in part at least, to erosion swings around the west and north sides of the hill at about 640 or 650 feet. But the handsomest feature is the series of elegant gravel bars on the east slope of the hill, in the open field. (Plate 13). These have altitudes (aneroid) as follows:

1. Shelf, with bare rock cliff behind it ....640 feet.
2. Gravel bar ....636 "

Intervening swampy tract or swale.

3. Bar of fine gravel ....630 "
4. Bar of fine gravel, close to 3....................627 "

Swale.

5. Broad bar ....627 "

Swale and wide interval.

6. Bar and gravel knolls, up to ....625 "

Wide interval.

7. Extended heavy bar ....615 "

Rough ground and bar below.

8. Southwestward extension of No. 7, with old gravel pits ....611 "

The upper limit of wave-work on this hill is against the rocky ledges and not clearly shown, but the gravel bars and terraces from about 650 feet downward are excellent. Plate 13 shows the series of bars, looking down from the rock cliff, No. 1.

It will be noted that the good bar construction is on the east side of the hill, the sheltered side, not on the north and west side where exposed to the heaviest winds. The more exposed side of the hill suffered erosion, and the detritus was swept around to the east side where the conditions favored bar-building. On isolated or exposed hills the constructional features should be sought on the lee side. It should, however, be recognized that these bars are rather fine material. Heavy bars of very coarse material, as cobbles or even bowlders may be constructed on slopes with strong wave action. It is a matter of several factors; quantity and character of the detritus, force and direction of the waves, depth of water, and character of the under-water slope. It is very difficult to predict where bars will occur.

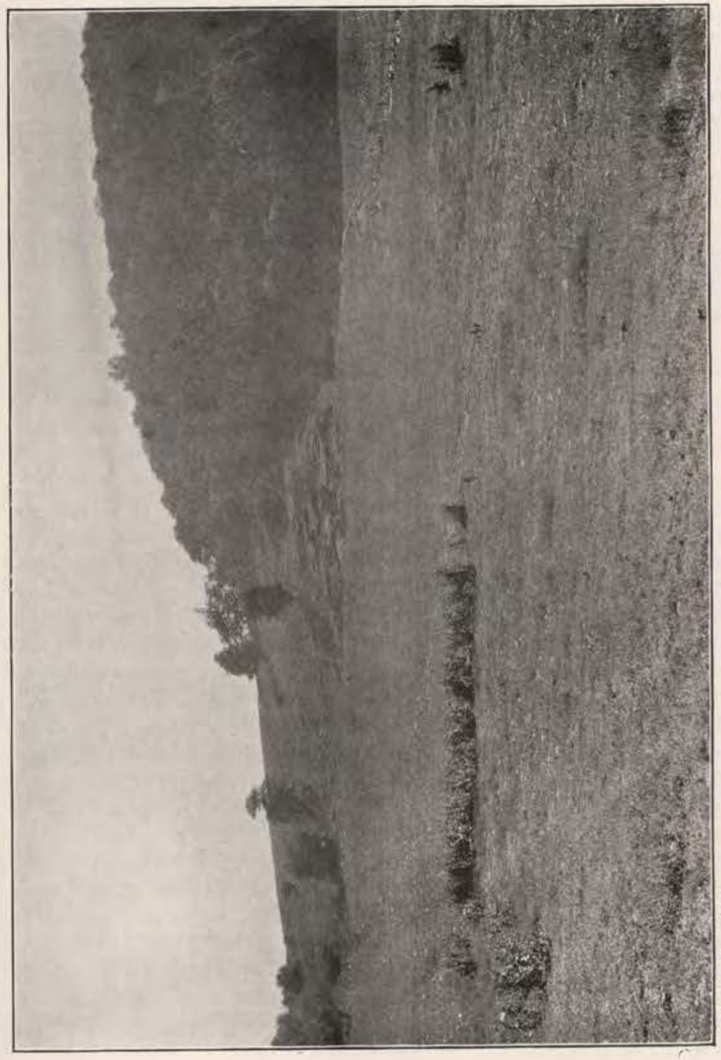
On the east side of Saxon Hill, the northeast corner of the Burlington sheet, is a sand plain reaching to the road where the altitude is given as 646 feet. The knoll on the east of the road shows cutting at yet higher level. The theoretic summit here is about 680 feet. Looking east from this point broad level plains at higher altitude are seen in the town of Jericho. On the west side of Saxon Hill are evidences of water erosion far above 600 feet, and sand dunes reach up to 610 feet, drifted from the plain below.

Mt. Philo, on the southwest corner of the map shows very clearly the erosive effects of the high waters on the west or most exposed side. This shows better at some distance and is seen very well from the trains on the Rutland R. R., two and one-half miles away. The cutting on the west side extends up to the summit level, about 640 feet, while the detritus from the erosion was swept around the south side and down the slope. The lower lines of water action are conspicuous.

The evidences of standing water at inferior levels are so abundant that extended description is unnecessary. The two hills northeast of Williston exhibit good rock cliffs and notchings. The south hill, a mile from Williston and the property of C. J. and C. S. Wright, carries a gravel bank with excavation at elevation of about 650 feet, on the south side.

Williston stands on a plain at 500 feet altitude. The slopes to the south were exposed to the full force of wave action by the northerly winds, and it might be expected that good evidence of wave-work would appear. Three roads pass up the slopes and give easy opportunity to examine the ground. No bars or cliffs appear, only a smoothness or evenness of surface, rather characteristic of wave-washed surfaces, but quite inconspicuous. The slopes are stony clay-till, loaded with bowlders, and resisted the

PLATE XII.



H. L. F. photo. SUMMIT GRAVEL BAR. SHORE OF CHAMPLAIN SEA.
Two miles southeast of Hinesburg. Altitude 660 feet. Looking southeast from lower bar.

wave erosion. This is a good example of the negative evidence in many exposed localities. The absence of evidence of standing water is unsafe basis for negative statement. A few positive features overbalance any amount of negation.

Montpelier District; Winooski Valley.

No topographic map is published for the area east of the Burlington quadrangle. The only data for altitudes, and not precise, are the levels of the Central Vermont R. R.

The waters of the Champlain sea extended southeast up the narrow Winooski valley to beyond Montpelier, and the terracing of the deposits on the valley walls are abundant and often conspicuous from the moving train. We have here a record of the same history as in the Connecticut valley (see 33) ; a narrow valley, deeply flooded with sea level waters, abundant inwash of detritus by tributary streams, and the benching of the deposits by wave erosion of the lowering waters, with some effect of outflow currents at the latest stage. The conditions were not that of a river but of an "inlet." One conclusive proof is the occurrence of thick deposits of finely laminated clays. A good example is seen at Waterbury. The electric line for Stowe climbs up the face of clay beds for 100 feet. At least 70 feet are exposed. Similar clay deposits, overlaid by the later sands and gravels, are found in all the deeper valleys, and constitute the bulk of the lower plains in the Connecticut, Champlain and Hudson valleys. The contorted structure sometimes seen was produced by the slumping due to their own weight.

The Winooski valley, with its southeast trend, lies practically on the Burlington isobase, and the summit marine plane is 670 or 675 feet. The elevated plains and terraces visible from the railroad are the lower and latest levels, the summit features being far back up the side valleys.

The Winooski river may be regarded as beginning at Montpelier, in the junction of several streams. The north, or Worcester branch bisects the city. The Dog river joins two miles west, at Montpelier Junction. The south and east branches unite about two miles southeast of the city. Many small streams dissect the valley walls. The crystalline rocks of the Green Mountains and the glacial drift supplied abundant material for delta construction, while the stream flow concentrated it in this section. But the existing terraces are only small remnants of the original deltas, for with the lifting of the land the vigorous rivers eroded the deposits and swept the detritus westward, down stream, to build plains at lower levels, and even as far as Burlington.

In the eastern part of the city of Montpelier is a handsome sand plain, easy to reach and convenient for study. It is known as "Seminary Hill" and is reached by the Seminary Hill street cars, which have their terminal at the north edge of the delta plain. The State Arsenal and many residences are located on the plain, which has just the height of the gilded dome of the State House. The altitude of the plain is about 670 feet, taking the Central Vermont station in the city as 529 feet. Merwin (26 p. 130) makes the back edge of the plain 675 feet, which is the precise theoretic figure for the summit plane of the Champlain sea. The full height delta of the North Branch must be found north some miles. Broad plains are visible up the valley from the Seminary plain, and evidences of the same waterlevel may be distinguished about the valley.

The summit delta of the Kingsbury and the east branches of the river is found at Fairmont station (East Montpelier) of the Montpelier and Wells River R. R. The delta filled the whole width of the valley, with the top at about the level of the station and declining downstream, westward, for two miles in a series of steps. The summit altitude is about 720 feet according to the railroad levels.

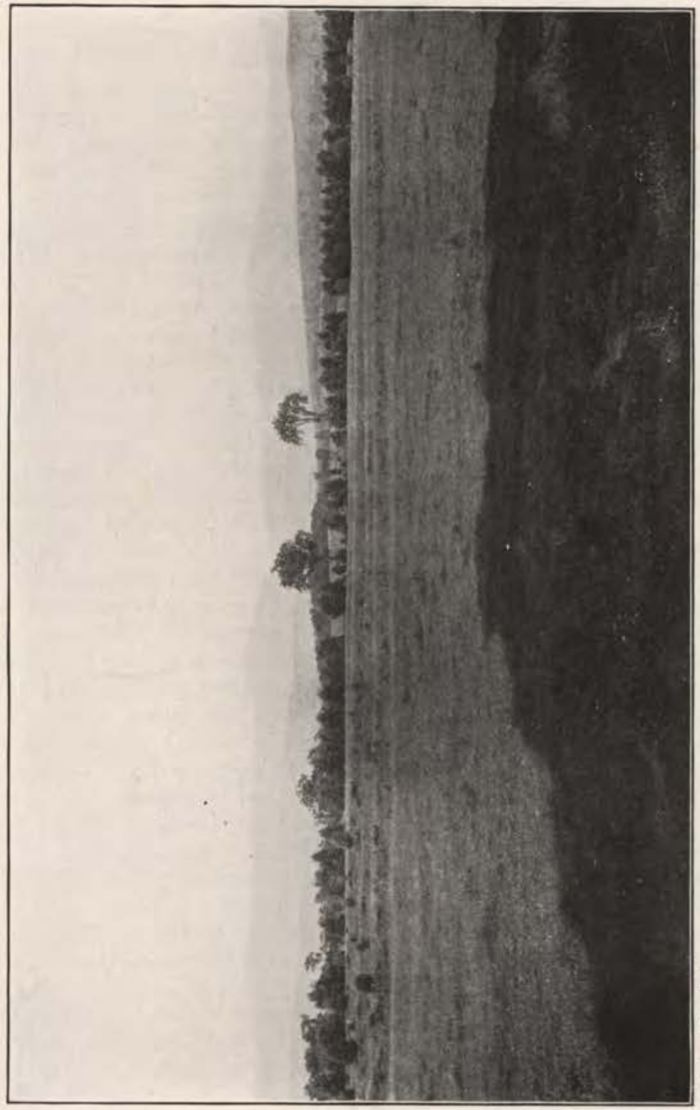
All the valley about Fairmont station and East Montpelier shows elegant terraces. And these terraced plains extend up the east branch of the Winooski river as far as Plainfield, reaching an altitude of 750 feet. The theoretic altitude of the Champlain sea at Plainfield is about 680 feet. The excess in altitude of the Plainfield plains, some 70 feet, is more than can be allowed for the gradation of the delta. Evidently there is some complication here with glacial lake waters. The explanation is at hand. Merwin has located an outlet channel at the head of Hollow Brook, three miles northeast of South Hinesburg, with altitude about 670 feet. This was the outlet of the latest and lowest glacial waters held in the Winooski basin, which we may call the Winooski lake. The high plains at Plainfield were built in the early and highest stage of this lake. The drop from the lake to the sea level was neither great nor sudden, and the delta at Fairmont carries the sea level terraces in its lower steps.

The relation of the Winooski lake to its predecessor, the Montpelier lake is told on later pages.

Up the south branch of the river, toward Barre, inferior deltas occur on both sides of the valley. These are clearly seen from the cars of the electric railway, and show the characteristic terracing by lowering waters. The Golf Links of the Country Club are on one of the terraces. Passing southward the water planes must decline about 2.5 feet per mile.

The massive high level delta southeast of the city of Barre, capping both sides of the deep ravine, is a glacial lake delta and must not be confused with the sea level waters. The theoretic plane of the latter is about 660 feet at Barre, while the high delta is much over 900 feet. This splendid delta once filled across the ravine and was the deposit of a branch of the Winooski river in the Montpelier glacial lake, the latter being held at the level

PLATE XIII.



H. L. F. photo.

SERIES OF SAND BARS ON EAST SLOPE OF NORTH WILLISTON HILL.

Looking east, down the beach from wave-eroded rock cliff. Bars about 45 feet beneath the theoretic summit plane.

of the Williamstown (Cutter Pond) outlet. This is noted later (page 38).

Morrisville District; Lamoille Valley.

The only topographic map now available is the Milton sheet, which covers the mouth of the river and up stream only to Fairfax. This map shows beautifully the lower detrital plains, from over 400 feet down to the present baselevel in Lake Champlain.

The general description of the Winooski valley and its Pleistocene history would apply almost perfectly to the Lamoille. It is a similar deep, narrow trench extending southeast through the mountains, and at first held glacial waters, and these succeeded by an extension of the Champlain sea. Hitchcock and Merwin have given some description of the static water phenomena in this valley (7, pages 245-246; 28, pages 131-134).

The Lamoille marine inlet reached up the valley to Hardwick. The theoretic altitude of the summit waters is 720-725 feet. As in the Winooski valley the detrital plains which are visible from the railroads in the valley are the later, inferior benchings. The full height plains must be sought toward the heads of the tributary valleys.

If the observer begins his exploration by train from Essex Junction he will have a splendid display of detrital plains, starting at 350 feet at the junction and with rising levels past Essex Center, Jericho, and Underhill. Northward the railroad rapidly falls to the Lamoille river, and the terraces there soon blend into the floodplain of the present river.

A grand display of delta plains is found at Morrisville and eastward. Here several streams joined the Lamoille waters and the volume of detritus was large, and quite filled this section of the valley. Extensive plains indicate the successive falling levels of the static water.

The business part of Morrisville is on a plain with altitude of 670 feet, taking the railroad station as 646 feet. Passing eastward by the highway a higher plain with abrupt front has frontal elevation of 720 feet, rising to 730 at the back. Another terrace, with a bar front, is 740 feet. Above this lies the handsome summit plain, with altitude of 750 feet. All the figures are by aneroid. The back edge of the summit sand plain, beyond which the ground is rolling and rough, is one mile from the post office, and near the house of Mr. Clayton S. Cornell.

The village cemetery is on the extensive part of the plain on the south side of the river. The entire width of the valley was probably filled in this section and partly reexcavated by stream erosion.

South of Morrisville along the road to Stowe the detrital plains, smoothed by the lowering waters of the Champlain sea, are beautifully displayed. The summit plains lie at the col or divide between the Lamoille and Winooski valleys, with altitude about 740 feet. Hitchcock gives the elevation as 745 feet.

From these figures it will be seen that while the lower terraces correlate with the summit level of the Champlain sea the upper terraces are too high. Here, again, we have complication with glacial waters, as in the Winooski valley. The later outlet was probably the same, the Hollow Brook channel. Some higher levels, toward and above 1000 feet, probably correlate with the Williamstown outlet.

These glacial features have been discussed by Merwin (28). Further description is deferred to a later chapter (page 38).

St. Albans District.

The St. Albans sheet covers the district.

In this area, between the Lamoille and Missisquoi valleys, the conditions were not favorable for strong development of the higher features by the Champlain sea, although the plains below 500 feet are well displayed. The theoretic summit altitude at the village is 740 feet, which is the figure for Covey pass on the north boundary of New York. In other words St. Albans lies on the isobase passing through the late outlet of the glacial lake Iroquois.

No streams of consequence poured into this area from the highlands, to build conspicuous deltas. The hills have a steep west face, against which the higher waters lay, and the ice sheet had smoothed the rock slopes and failed to leave detritus from which the waves might construct gravel bars. The summit features are weak and require skillful search. But there are a few localities where the writer has noted highlevel shore features.

On the east edge of the map, east of Green's Corners, are good sand plains at 600 feet and up to 680. At the latter height, which is on the high point in the east and west road, and precisely on the border of the map, is a fair embankment of wave construction. This is about 80 feet beneath the theoretic summit level.

Northeast of the village and opposite Aldis Hill distinct beach lines can be seen on the hillside, east of the highway. The height is 720 to 740 feet.

East of the village and on the Fairfield road beyond the four-corners, with height 567 feet, are two series of delta benches and weak bars. These lie along the gulleys, of which one lies north of the road and three on the south side. The lower terraces range from 655 to 680 feet, and the higher series from 715 to 740 feet, the theoretic altitude. These little deltas, built by the weak brooks, are very pretty features, and good examples of what may be found in many places by careful study. They afford fine material for nature students.

PLATE XIV.

H. L. F. photo.

WAVE-CUT CLIFF AND WAVE-BUILT TERRACE.
Southwest face of Williston North Hill. Looking west.

Three and one-half miles south of the village and a mile east is the village reservoir and school No. 9. West from the reservoir, toward the three corners the summit plain is seen at 740 feet. A residence stands on the level. The same level occurs on the road leading south. At the school house are sand knolls which are dunes and kames. Careful discrimination is required to distinguish between glacial gravels (kames) and wind made sand knolls (dunes) on the one hand and stream deltas on the other.

South and southeast from the reservoir, and on the Milton sheet, many water-leveled tracts at the summit plane, about 720 feet, may be found near the schools Nos. 14, 3 and 13. Also farther south on the road to Fairfax village.

Four miles southeast on the Fairfield road is the Swamp School, and four corners. Here is a beautiful dissected delta with the summit 725 feet. East of the corners is a lower plain at 675 to 665 feet.

Missisquoi Valley and Lake Memphremagog District.

The lower reach of the Missisquoi river with its interesting delta in Champlain are shown on the St. Albans sheet. For the territory eastward along the north boundary of the State no topographic map is published.

On the St. Albans sheet expanses of white indicate the lower terraces of the river delta in the Champlain sea up to at least 340 feet. For the summit levels we must go far up the valleys of the river and its tributaries.

Along the northern line of the State east of the St. Albans quadrangle the land surface is mostly far higher than the marine plane. The Green Mountains extend as ridges into Canada with intervening deep valleys. Three of these valleys with north and south direction were so low at the close of glacial time that they held tongues of the sea level waters. These valleys are, Lake Memphremagog basin and the Barton river; the upper or headwaters portion of the Missisquoi valley, declining northward into Canada; and the middle portion of the Missisquoi valley where it returns with southward flow into Vermont. In a generalized way these are shown in the map, Plate I.

As this portion of the State has not been reached by the topographic survey the altitudes are by aneroid, using the elevations of the railroad stations as datum. The figures for altitudes in this and the following chapter must not be regarded as precise, but are reliable within narrow limits.

At Richford the higher marine plane is represented by a good display of bars and benches on the summit of the hill northeast of the station, owned by Maurice Smith. The topmost bar is level with the rocky summit of the hill, with altitude of about 780 feet, taking the Central Vermont track at the station as 500 feet. Good benches curve about the hill on the east, north and northwest sides down to about 725 feet. Terraces at lower levels appear in the connecting valleys.

The summit levels will be found up the valleys having heavy drainage, represented by delta gravel plains. The theoretic altitudes may be determined for different places by consulting the map of isobases, Plate I.

At North Troy an extensive lower plain fills the valley, with elevation a few feet over the railroad, the station being 604 feet. Higher terraces are evident at altitudes about 630 and 650, and up to about 675 feet. Features do not show here at the theoretic summit, which is near 800 feet. Summit deltas will be found southward, up the valley, at Troy or Westfield.

At Newport Center the lower plains are broad and conspicuous. Taking the station as 777 feet, the plain in the northeastern part of the village is 800 feet. Northwest of the village gravel has been taken from knolls which have been shaped into a broad bar-like swell, at about 760 feet.

At Newport and West Derby we find the usual strong, lower sand and gravel filling of the valley. The station is given as 691 feet. Lake Memphremagog is about 685 at high, or 682 at low water. A strong plain appears north of the station, apparently about 20 feet over the lake.

The village of West Derby is built on a sand plain with altitude at the corners by the band pavilion of 765 feet. The summit level of the plain is taken as 785 or 790 feet, at the east edge of the village.

Passing south from Newport, up the valley of Barton river, very beautiful plains and terraces are seen at many, and rising, levels. At Orleans they may be studied on both sides of the valley. The eastern part of the village is on a terrace at about 800 feet, taking the station as 741. The detrital plains continue to Barton, where the valley bottom rises above the marine plane.

In this study it should be remembered that the heads of the delta fillings may be graded above the plane of the standing water, being really an extension of the stream floodplain.

At Derby village, several miles east of Newport, splendid sand plains occur. The village is on a plain at about 1025 feet. Other extensive plains lie east and west of the village at 1010 and 1015 feet. These are proof of highlevel glacial waters in the Memphremagog basin. Hitchcock has recognized the glacial waters and has given the appropriate name, Glacial Lake Memphremagog. His description is found in titles 7, pages 247-249; and 9, pages 200-203.

There is opportunity in these valleys in northern Vermont for very interesting exploration by students of this Pleistocene history. But not until the topographic sheets are available can the levels be traced and relationships determined with precision.

CONNECTICUT VALLEY.

Waters confluent with the ocean lay not only along the west and north sides of the State of Vermont but also along nearly the whole extent of the east side. The valley of the Connecticut river was occupied by sea level waters, following the receding ice front northward from Long Island Sound. These waters extended as far north as Lyndonville, in the Passumpsic valley, this valley being the proper northward extension of the ancient Connecticut. Above Barnet the present Connecticut river lies in a higher, narrow channel which was originally a tributary of the main valley.

As described in the preceding chapter the ocean level waters along the north edge of the State reached southward up the Barton valley from the Memphremagog basin as far as to Barton village. Hence the distance along the eastern side of the State which separated the waters of the Champlain sea from the Connecticut inlet of Long Island Sound was the short stretch between Lyndonville and Barton, about 15 miles. This is shown in the map, Plate I. The high land in Sutton town, traversed by the Boston and Maine R. R. at its summit of grade was the narrow isthmus which separated the inlets of Atlantic waters.

The extensive and conspicuous plains and terraces throughout the Connecticut valley, below Barnet, did not escape the attention of travellers and geologists, and have been the subject of extended writing and serious discussion. The important study in the New Hampshire-Vermont section was made by Warren Upham (titles 10, 11), while the Massachusetts and Connecticut section was treated by James D. Dana in numerous articles (title 15). These authors recognized that the lowest plains in the valley were formed in marine submergence, but the terraces above the very lowest were attributed to river flow, when the river was greatly augmented by the glacial flood from the melting of the Labradorian ice sheet.

The present writer has discussed this matter in a recent article (33) and extended argument is no longer necessary. All the complexities, inconsistencies and difficulties which were involved in the river theory, and which were never solved, are swept aside by the fact of low land altitude and deep submergence. The latter is regarded as a fact and no longer a theory.

One fact which has not been properly considered, though it was one of Dana's puzzles, is the existence of thick deposits of fine clay, which is inconsistent with the conception of river flow. The finely laminated clays, proof of quiet water, are found far north in the narrow valley. Plate XV is from a photograph of these clays on the west side of the valley, by the highway, about five miles north of Wells River. At Wells River the clay beds are widely shown and are used in manufacture of brick.

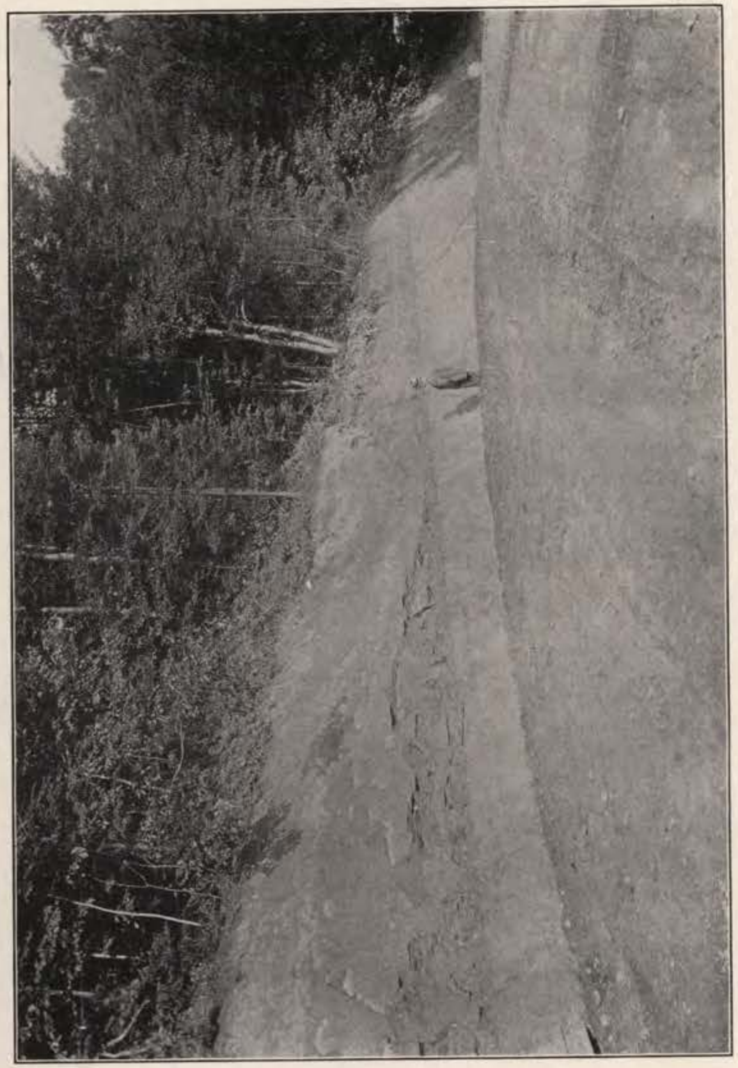
The narrower section of the Connecticut valley, from Hartford north to Lyndonville, is some 200 miles. It might be thought that in such valley considerable current would be necessary to carry the glacial flood, even if the water was an inlet of the sea. But the depth of water must be considered. At Hartford, Conn., the depth of water at the initial or summit level was 250 feet, and at Barnet the depth was the same. With such great depth of water the whole length of the valley the surface gradient and current was very small. The theoretic marine plane rises from 250 feet at Hartford to 700 feet at Barnet.

But if the surface slope and current in the open valley are negligible elements they must be recognized in the study of phenomena in the side or tributary valleys. When the summit of the standing water in the open valley has been determined, usually from weak and perhaps uncertain features, it will be found that the gravel terraces up the side valleys may rapidly increase in altitude, specially if the tributary valley is narrow and the volume of detritus had been large, or of coarse materials. The slope is steepest and most noticeable on the delta of the tributary stream, which may be far inland and the altitude of the highest gravel plains in the side valley will usually be far above the theoretic marine plane. For example, at Barnet the theoretic plane is 700 feet above tide. Taking the railroad station as 452 feet, the head of the Stevens creek delta, at the corners below the Barnet Center Church, is found to be 730 feet, a rise of 30 feet in about three miles. Similar conditions will be found in nearly every tributary valley.

Up the lateral or tributary valleys the deltas will be found dissected and often largely swept away by the later stream flow. They may grade up into the old floodplain of the stream, far above the marine plane. It is not practicable to determine the precise altitude of the standing water surface on the delta filling of a valley. This should be determined in the adjacent open valley.

It may be desirable to make a separate report on the Connecticut valley features, and in the present writing only the broader facts are given, with a few details of particular localities as examples. The maps will show the amount of depression of the valley in glacial time similar to that of the Champlain valley (or the converse, the amount of postglacial uplift) and the extent of the sea level flood. The isobasal lines indicate approximately the amount of the down and up movement and the present altitude of the marine plane. It will be seen that the summit level of the waters at Vernon, in the southeast corner of the State, is 400 feet, and that the altitude increases to 675 feet at Wells River and to 740 feet at Lyndonville, in the Passumpsic valley, the extreme northern reach.

PLATE XV.



H. L. F. photo. LAMINATED BRICK CLAY.

Four miles north of Wells River. Highway in the foreground. Proof of deep and quiet water.

The clay deposits, sand plains, and terraces are more extensive at the mouths of tributary streams which swept into the open valley a large amount of detritus. It is in such localities that the shore features marking the summit level will usually be found in better form. In the stretches in the open valley between the heavy deltas the initial shore line is likely to be weak and inconspicuous and often indeterminate. But good features sometimes occur where least expected. Little deltas on small brooks or on gullies of stormwash are very good evidence of the highest stand of the water.

As already stated, the sea level water reached northward up the Passumpsic valley to the vicinity of Lyndonville. North of the village a few miles the ancient floodplains are distinctly above the plains of the present river. Northward the two plains converge and finally coincide. Southward toward St. Johnsbury the terraces lie in good form, and decidedly above any modern drainage.

The upper part of St. Johnsbury village is on a terrace level which appears up and down the valley. Taking the railroad station as 556 feet the village plain is about 665 feet. The theoretic level is here about 720 feet, but evidences of standing water appear about the valley slopes in weak terraces, notches and smoothings 20 or more feet higher. This is much larger discrepancy than usual, between the theoretic figure and the field evidence. Perhaps the railroad elevation is too high.

About the village of Barnet excellent terraces appear up to 645 feet, using the railroad station as 452. The delta of Stevens creek has been noted.

Between Barnet and Wells River the lower plains are very prominent and higher terraces conspicuous. The summit shore line appears occasionally as benches or horizontal allineation on the deforested hillsides, and will certainly be found in good development on deltas and up the side valleys. The lower plains are largely clay, as throughout this and the Champlain, Winooski and Lamoille valleys. The clays shown in Plate 15 lie at about 450 feet, and were deposited in water over 250 feet deep. At Wells River a brick factory using the clays is about 530 feet altitude, which is 100 feet over present valley bottom, and 145 feet beneath the marine plane (675), taking the railroad station as 435 feet.

Strong water planes lie on the west side of the valley at Wells River, at the full theoretic height, about 675 feet. These may be clearly seen from the hill north of the railway bridge.

Passing up the valley of Wells River on the way to Montpelier elegant gravel plains appear, now eroded but which once filled the narrow tributary valley. These continue to beyond South Ryegate, reaching an elevation of about 750 feet, according to the railroad levels. This gives a gradation of about 75 feet in the 10 miles, or 10 feet per mile, the same as on Stevens creek, west from Barnet. At Groton the river is clearly above any effect of standing water, the channel being cut in glacial materials.

Detailed description of the valley terraces may be found in Upham's article (11), with good maps. The striking lack of detrital plains in the valley of the Connecticut river above Barnet is now explained by the fact that it was above the marine plane and hence not occupied by slack water.

There is little complication of these phenomena with those of glacial waters in the Connecticut valley. Since the theory of river work has been found untenable to account for the high terraces appeal has been made by some geologists to local glacial waters, lateral pondings along the ice margin. The southward trend of the tributary valleys did not favor glacial lakes. The lobation of the ice front in the Vermont section of the valley must have been too small and weak to act as an effective dam for any length of time. Any possible glacial pondings along the sides of the valley must have been ephemeral, fluctuating in level, variable in altitude, and generally ineffective.

GLACIAL LAKES.

It is not the purpose of the present report to describe in detail or discuss at length the highlevel waters held up in the valleys by the damming effect of the glacier. But it is necessary to clearly recognize the fact of the glacial lakes so as to prevent confusion of the products of these waters with those of the sea level waters. It is not yet possible to always clearly differentiate the glacial from the marine, and it was inevitable that they should have been confused in the past. The study is largely a close determination of altitudes of the deformed planes, and the complete history of the glacial waters of Vermont cannot be written until all the State is topographically mapped, so that the height of all the lower cols, or possible outlet channels, are known with precision and the relation in position of the ice barrier to the several valleys can be reasonably determined.

Some mention of the glacial waters has been made in the preceding chapters. The subject will be briefly reviewed in a general way.

Two geologists deserve credit for their study and interpretation of the glacial features in the interior valleys of the State, C. H. Hitchcock and H. E. Merwin. Special references will be given below.

The reader can readily understand that the south margin of the waning ice sheet constituted a dam across the valleys. In those valleys which declined northward, or sloped down toward the ice front, waters must have been held up to the level of the lowest escape. It will be evident that south of divides or in the valleys which sloped freely away from the glacier no glacial lakes would be held. This applies to the Connecticut valley and to all its

tributary valleys in Vermont, speaking broadly. It is possible that in some cases the lobation of the ice front in the Connecticut valley may have temporarily blocked the mouths of some of the streams flowing east or southeast. No long-lived lakes were held in the valleys of Connecticut drainage.

The earliest, highest and more localized waters were in the higher or headwater portions of the valleys draining toward the Champlain and Hudson valleys, and there were many such local and ephemeral lakes. The large, persistent and important glacial lakes were restricted to the Otter, Winooski and Lamoille valleys and the Memphremagog basin. This was recognized by Hitchcock ten years ago. He says:

"So it is conceivable that at one time Glacial Lake Memphremagog discharged though the Elligo outlet into the Lamoille and the Glacial Lamoille discharged through the Stowe strait to the Winooski, and even this later stream poured through the Williamstown gap into White river, and eventually into the Connecticut. This condition of things could prevail only when the ice filled up Lake Champlain so high that there was no chance for the water to be discharged except through an eastern outlet." (7, page 249).

"* * * but without doubt there was a period when water spilled over the East Dorset divide from the Champlain body and contributed to the growth of the flood plain of the Batten Kill." (7, page 241).

Hitchcock's view is correct, with only one change. The pass at Stowe was not a glacial outlet as it was flooded by the sea level waters, into which the glacial waters had been previously lowered.

The earliest of these lakes, being the most southerly, was the Wallingford lake, in the head of the Otter valley, with outlet at East Dorset. This has been sufficiently described in connection with the complication of features in the Rutland district (page 18).

When the ice front passed north of Rutland the ocean level waters occupied the lower ground west of the divide between Champlain and Connecticut drainage and no glacial lake of any size existed in the Champlain area until the ice uncovered some of the Winooski basin.

The earliest glacial lakes in the Winooski basin were the local lakes in the valleys of the Mad and Dog rivers and the south branch of the Winooski. The one in the Dog valley has been noted by Merwin (28; pages 124-127). The pass at the head of the Winooski south branch, early recognized by Hitchcock and also described by Merwin (28; pages 127-128), is the lowest pass across the divide between Connecticut and Champlain drainage. It lies some two and one-half miles south of Williamstown, by Cutter Pond, on land of L. D. Martin. The altitude of the pass is given by Hitchcock as 908 but Merwin and the writer make it 890 feet.

A distinctive name for the glacial water held at the level of the Cutter Pond outlet is Lake Montpelier. Merwin's name, "First Lake Winooski," was applied to some lower water which he conceived had escape "beneath or around the ice into the Champlain valley," a condition highly improbable.

Evidences of the glacial lake Montpelier must occur throughout the east part of the Winooski basin, or about the limits of Washington county. If we take the depth of water over the outlet at the latest flow as ten feet it makes the water surface there about 900 feet. To calculate the water plane at any point northward we must add 2.5 feet per mile. At Montpelier the closing plane would be 930 feet. Undoubtedly higher lake features will be found in the extent of the basin, specially in the south and east portion, due to some blockade of glacial drift in the pass which gave a higher initial stand of the glacial waters. On deltas, in narrow valleys, some allowance must be made for the grading or upbuilding at the head of the delta.

Lake Montpelier must have existed until the ice sheet uncovered some outlet lower than the Cutter Pond outlet. This appears to have been the Hollow Brook channel, 16 miles southeast of Burlington, and 5 miles southeast of Hinesburg. This rock channel, first noted by Merwin (28; page 119), was probably the lowest and latest control of glacial waters in the Winooski basin, and when abandoned the sea level waters took possession. This lake we may call Lake Winooski, as it covered all the Winooski valley east of about Richmond that lay beneath a plane now represented at Hollow Brook by 680 to 700 feet or over. The earliest phase of Lake Winooski may have been considerably over 680 feet, on account of original drift filling in the hollow which the outlet river had to remove. The waters probably occupied the Lamoille valley, being confluent through the Stowe pass. Broad sand plains in the Winooski and Lamoille valleys must be credited to this glacial water. As the latest phase of the lake was only 30 or 40 feet over the marine level the lower and subaqueous plains may blend into or be confused with the sea level deposits.

This is illustrated by the plains and terraces at Hardwick, Morrisville, Stowe, Fairmont and Plainfield. The lower terraces correlate with the marine plane; the upper terraces are too high. Following is an example of the analysis. At Plainfield the theoretic marine plane is about 680 feet. The sand plains reach up to 750 feet. Hollow Brook channel is today 670 feet. The distance between the isobases of the outlet and of Plainfield is about 10 miles, which gives a difference due to tilting of 25 feet. If to the channel height, 670, we add 10 feet for depth of the river, and the 25 feet differential, we have an altitude of 705 feet. And we have not included the height of the delta summit above the static

water plane; nor the higher level of the initial lake as held up by some drift blockade of unknown amount in the outlet hollow.

Merwin's water that he calls Lake Mansfield (page 136) seems to be the equivalent of Winooski.

If the Lamoille valley held any distinct, separate glacial waters it must have been for a brief episode. No clear channel exists at Stowe, the only possible outlet for any length of time. It seems probable that the sea level waters took possession of the Lamoille valley very soon after they invaded the Winooski.

With present information the writer is inclined to the opinion that at an early stage of the ice-front recession one glacial water body covered the Memphremagog, the Lamoille and the Winooski valleys, with its outlet at Cutter Pond. Hitchcock has hinted at this. The reason for this is that splendid sand plains occur in the Memphremagog basin, about Newport and Derby far above 1000 feet (see 7, page 248). These are too high to correlate with the Elligo Ponds outlet near Craftsbury, and no other low outlet is known. Taking the postglacial deformation as 2.5 feet per mile and the distance between Cutter Pond outlet and Derby as 68 miles we have a differential uplift of 170 feet. Adding this to the present height of the outlet, 890 feet, we have 1060 feet. All these elevations are by aneroid and subject to correction. Hitchcock gives terraces at Derby and Salem as 1060 and upwards. Some factors may now be overlooked which will give a different explanation. It is possible that the pass north of Woodbury was an outlet for the Derby glacial waters.

Certainly at a later stage the Memphremagog waters outflowed by the Elligo Ponds outlet, about 890 feet, through Alder brook valley into Lamoille waters, either Lake Winooski or the sea level waters. Good sand plains are found about Lake Memphremagog between 900 and 1000 feet which correlate with the Elligo outlet.

On many salients, steep slopes facing north or west, abandoned channels cut by glacial stream flow between the ice front and the land slope may be found. These drained to lower levels the glacial waters held in valleys or embayments by the ice barrier. They are interesting features for the student of earth science. Such channels have been observed above the marine level at Hinesburg, Bristol, East Middlebury, Forestdale and Brandon. The deltas at these localities represent the final downflow of either land or glacial drainage.

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EVIDENCE FOR AND AGAINST THE FORMER EXISTENCE OF LOCAL GLACIERS IN VERMONT.

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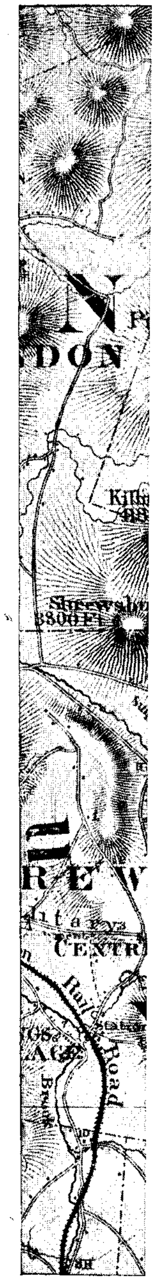
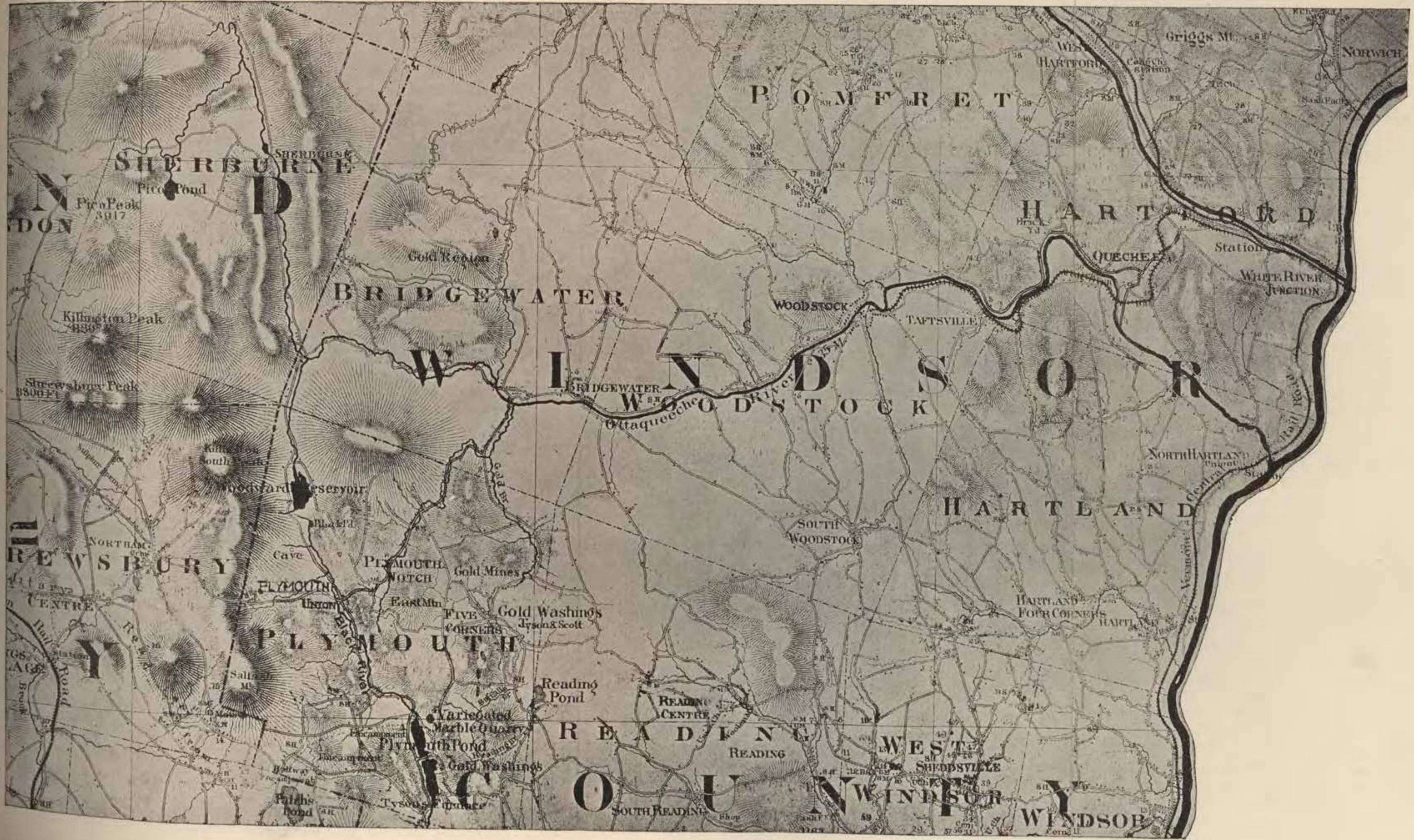
INTRODUCTION.

Among the puzzling questions of Vermont geology, none has been more mystifying than that of the former existence of glaciers of the alpine type among the Green Mountains. Although the problem met with the attention of pioneers in geologic research in northern New England, including Louis Agassiz, the distinguished founder of the glacial theory, it can scarcely be said to have been solved. The reports of C. B. Adams, the first state geologist, from 1845 to 1848, and that of Edward Hitchcock, whose survey extended from 1856 to 1860, contain brief yet interesting descriptions and discussions of morainelike deposits and other features suggestive of glaciation either by Alpine glaciers or by an ice sheet such as Agassiz conceived. In the final report of 1861, the view is set forth that local glaciers like those of the Alps did indeed exist in Vermont, in the valleys of the Ottaquechee, the Black, and the White rivers. Nearly fifty years after this, in a report on the geology of the Hanover Quadrangle[1] Professor Charles H. Hitchcock, who had been his father's assistant on the Survey of '61, testified again to the former existence of an alpine glacier in the valley of the Ottaquechee, and presented additional evidence to support that view. Inasmuch as the earlier observations were made when glacial geology, if not properly in its infancy, was at least in a stage of retarded growth, owing to the scepticism of American geologists towards the extraordinary ice-sheet theory of Agassiz, and inasmuch as the later studies were confined to one locality, it has seemed worth while to examine the evidence in question, applying to it more modern conceptions of the records which valley glaciers leave behind them, and to gather additional evidence, if there

[1] C. H. Hitchcock, Geology of the Hanover Quadrangle: State Geologist Vermont Rept., vol. 6, pp. 139-186, Pl. xxiii-xxxvii, Fig. 4. 1908.





MAP OF THE OTTAQUECHEE-BLACK RIVER COUNTRY.

might be any, in places hitherto unstudied, though at least equally favorable for the development of alpine glaciers. It has been hoped thus either to prove or to disprove the former existence of local glaciers among the Green Mountains. My interest in the question was first aroused by a brief examination of some of the evidence in the Ottaquechee valley, during a trip from Rutland to Hanover, New Hampshire, at the summer meeting of the American Association for the Advancement of Science, in 1908, under the guidance of Professor Hitchcock. Since that time, studies of local and regional glaciation in the White Mountains of New Hampshire have increased this interest, and have prompted the present undertaking. The publication of the Woodstock Quadrangle by the U. S. Geological Survey in 1913 has provided new and useful material for the work.

Upon the basis of facts set forth in the following pages, it is the opinion of the present writer (1) that no trustworthy evidence of the former existence of glaciers of the alpine type occurs in the valleys already mentioned; and (2) that a complete absence of records of local glaciers in the places most favorable to them,—around the highest peaks of the Green Mountain range—makes it extremely unlikely that local glaciers developed at any time during the Ice Age in the Green Mountains. The study is not merely of local interest, because it throws light upon the condition of climate which prevailed in northern New England at the time when the continental ice sheet was retiring into Canada. Instead of leaving local snowfields and alpine glaciers on the Green and White Mountains, as hitherto supposed, the departing ice sheet seems to have left these elevated districts about as free from snow as they are today.

PREVIOUS STUDIES OF THE PROBLEM.

The history of successive efforts to answer the question regarding former local glaciers in Vermont is an interesting one; for it shows how investigators have gradually been led from a position of unbelief in the theory of Louis Agassiz to a position of full reliance upon it.

In the early '40's, when Adams' first survey of Vermont was inaugurated, geologists were prone to confuse ice sheets with local valley glaciers. This was natural enough, since the great polar ice caps were little known then, while valley glaciers of the Alps had been studied and described in detail by Agassiz, de Charpentier, and other European scientists. Like his contemporaries, Professor Adams saw in the heavily scrubbed form of exposed ledges and hillsides, the grooved surfaces of the rock, and the dispersion of rock debris from known sources in a southerly direction the work of some mighty agency which had moved across Vermont from north to south, acting alike at all levels.

Louis Agassiz insisted that this agency was a sheet of ice, so widespread that it covered the northern part of the continent, and so thick that it overtopped the New England mountains; but Adams, Edward Hitchcock, Dr. Charles T. Jackson, and other geological observers in New England confessed themselves unable to accept so highly imaginative a theory, and adopted, in its place, that of Murchison, a distinguished English geologist. This theory attributed all the phenomena to powerful "waves of translation" which had swept over the land while it was emerging from the sea, the drifting huge earth-filled icebergs from the north polar regions toward the equator. To be sure, the exponents of this "drift theory" did not altogether reject the idea of local glaciers of the alpine type in highlands like the White and Green Mountains, during the submergence and reelevation of northern New England. Adams considered the possibility of glaciers of this sort, in his field studies of 1845 and 1846, but reached a negative conclusion.

"If glaciers could have accumulated anywhere, it would have been in the valleys of the Lamoille and Winooski, where however, the perfect preservation of the drift striae and scratches, in a direction up these valleys prove that in them no glacial agency has been exerted."[1]

"Powerful waves of translation moving along the great masses of loose material 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 account for the facts."[2]

In his report for the following year, however, Adams stated that further study of the peculiar scrubbed ledge in the Winooski valley, in Bolton, on the vertical face of which were horizontal grooves, (see Pl. XVIIIa) which he had had the pleasure of showing to Louis Agassiz, had forced him to admit that an ice sheet, alone, seemed to provide the right dynamics, although he must still reject the theory as preposterous.[3] In this attitude, Adams was supported by his friend and former teacher, Prof. Edward Hitchcock, who wrote him on Sept. 1, 1846:

"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."[4]

Adams therefore seems to have held the opinion that neither local glaciers nor a continental ice sheet had ever covered Vermont.

[1] Adams, C. B., Second Annual Report on the Geology of the State of Vermont, p. 141, 1846.
[2] Op. cit., p. 140.
[3] Adams, C. B., Third Annual Report on the Geology of the State of Vermont: pp. 21-22, 1847.
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PLATE XVIII.

A. GLACIER WORN LEDGE, BOLTON.

B. BLACK RIVER VALLEY NEAR PLYMOUTH UNION.

Ten years after the publication of Adams' report, attention was again directed—and more clearly than before—to the question of former glaciers. Although he followed Adams in attributing the southward grooving and scratching of ledges and the southward dispersal of fragments to an aqueous "drift agency" rather than a solid ice sheet, Edward Hitchcock found reason to accept local glaciers as a cooperating agency. He committed the task of interpreting the surficial geology very largely to his son, Charles; but the statements relating to local glaciers appear to be vouched for by both. In a section entitled "Striation, Planishing, and Embossment by Ancient Glaciers in Vermont," are somewhat detailed descriptions of those features in the valleys of the Ottaquechee, Black, and other rivers, which seemed to the two Hitchcocks to establish the former presence in them of local glaciers. Concluding his descriptions of the terminal moraine of the Black river glacier, at Plymouth ponds, the elder Hitchcock said:

"If this was not the moraine of a glacier, we can hardly hope to convince the public that there are any in Vermont."[1]

Among the "forms of modified drift" described by the geologists of the Survey of 1854-61, are "moraine terraces." These are said to be differentiated from normal river terraces by "exhibiting great irregularity of surface, elevations of gravel and sand, with correspondent depressions of most singular and scarcely describable forms. The term 'moraine' is prefixed to terrace under the impression that stranded ice, as well as water, was concerned in their production."[2] It is not definitely stated whether the agency is conceived to have been grounded icebergs or half submerged valley glaciers.

The Hitchcock report of 1861, therefore, maintains that while drifting icebergs and not Agassiz's great ice sheet was the fundamental process, nevertheless mountain glaciers like those studied by Agassiz in the Alps were numerous. Thus, Hitchcock's position is a compromise between the theory of waves of translation in its early form and the glacial theory of Agassiz, in which the latter is given a subordinate place.

During the following half century, so fruitful in field studies of glacial phenomena elsewhere in North America, the truth of Agassiz's fundamental conception of a former ice-wrapped continent became thoroughly established. Through lines of evidence so various as to seem at first wholly independent, the works of the mysterious "drift agency" were gradually correlated and recognized to be, in fact, the work of a great ice sheet similar to those of Greenland and Antarctica. What Agassiz's brilliant imagination had pictured gradually came to be regarded as a real geologic agency. The grooves and transported stones no longer

[1] Hitchcock, Edward, in Report on the Geology of Vermont, vol. 1, p. 86, 1861.
[2] Op. cit., p. 121.

seemed to mark the paths of grounding icebergs, but the course of an extinct continental glacier. Among those who contributed early and unremittingly to the establishment of the ice-sheet theory was Charles Hitchcock. By him a voluminous list of observations of striae in New Hampshire was prepared and a variety of glacial features were studied and classified, and the discovery was made, in 1875, that Mt. Washington itself—the highest point in northeastern North America—had been buried by solid ice moving from northwest to southeast. The interpretation that the younger Hitchcock gave to Vermont surface geology therefore differed fundamentally from that which his father had given it. He laid aside the old theory of drifting icebergs in favor of the theory of a great ice sheet, which had spread slowly across the region without regard to hill or valley.

In one respect, however, Professor Charles Hitchcock has maintained the views of the 1861 report,—namely, as regards the glaciation of certain valleys by local glaciers, after the withdrawal of the ice sheet. This view is set forth in detail for the valley of the Ottaquechee, in his report of 1909, as will be shown by quotations in the following pages. We have, therefore, in this recent work a third stage in the development of thought regarding glaciation on the mountains of Vermont,—namely, that after they had been covered and overridden by the North American ice-sheet they were for a time occupied by local snowfields and valley glaciers.

Anticipating a little the conclusions reached in the present paper, it will be seen that the fourth stage consists in rejecting the idea of local glaciers altogether and adopting Agassiz's great ice sheet as the agency responsible for all the glacial features in Vermont.

QUECHEE LOCAL GLACIER.

The "local glacier" of the Ottaquechee valley was one of the first to be suspected in Vermont. The belief in it rests upon more evidence than in any other case, and it is the only one whose existence has been advocated in a geologic report during the last decade. Signs of this alleged glacier were first detected in 1854 by Edward Hitchcock and his son, and were described in the 1861 report. The evidence consisted in (1) local moraines of stratified drift, in Woodstock and Bridgewater, (2) rounded slopes on the hillsides along the southern branch of the river, in Bridgewater and Plymouth, which suggested a movement of ice northeastward, down the valley, in opposition to the usual southward movement of the "drift agency," and (3) scoured western sides of certain hills along the more northerly branch of the river in Bridgewater and Sherburne (see Pl. XVII). Since copies of this report are now scarce, a full quotation is given below of the passage in which the local glacier is described.

"Another example of the traces of the action of ancient glaciers, not so striking, however, as those already detailed at the headwaters of the White river occurs on the Quechee river above Woodstock. In ascending that stream above that village we meet, within a mile or so, accumulations of detritus on the north bank, which we refer to moraines that have been subsequently considerably modified by water. Several miles farther west we found a still more decided example, just before reaching the village of Bridgewater. Here the detritus seems once to have extended entirely across the valley, but has been worn away by the river on one side, as we see in the vicinity of Chamouni in Savoy, where we are certain that glaciers were the cause. The only difference seems to be that in Vermont water has subsequently produced greater modification than in the Alps.

In following up the south branch of Quechee river, which comes in from Plymouth, we find the west and southwest sides of the mountains to be rounded, though the striae seemed to be mostly obliterated. On the more northerly branch of the river, at least as far as the gold mine in Bridgewater, where an auriferous quartz vein has been worked, we found the west side of the hills to be the stoss side, as it would be if a glacier once descended from the crest of the Green Mountains down the valleys of Quechee. And though our explorations have been far more limited than we could wish in that region, we strongly incline to the belief that a system of glaciers once occupied the head valleys of the Quechee as well as those of the White river.[1]

The somewhat slender evidence which thus early suggested the theory of local glaciation gained support from subsequent studies by Professor Charles H. Hitchcock, whose results are recorded in detail in his "Geology of the Hanover Quadrangle," in 1908.[2]

In this paper, Professor Hitchcock reiterated the evidence of the 1861 report, locating more precisely the two branches of the glacier; one in the valley of the south branch heading above Pinney Hollow, in Plymouth, and the other in that of the main branch, in Sherburne. As new evidence he described certain features farther down the valley, east of Woodstock, particularly: (1) an extensive overwash plain of morainic character at Dewey's Mills, near Quechee; (2) terraced deposits of sand and gravel in the valley behind this morainic barrier, which he assigned to a glacial lake; (3) an esker, closely associated with the terrace deposits of the "glacial lake" above Quechee; (4) an interrupted train of sand which reaches from an alleged outlet of this glacial lake down the valley to the Connecticut river in North Hartland; (5) glacial striae in or near the valley, below the overwash plain, running S. 13°E., or straight down the valley; and (6) glacial

[1] Hitchcock, Edward, Op. cit., vol. 1, pp. 85-86.
[2] Hitchcock, C. H., Op. cit.

smoothing of the steep eastern side of the valley, in a general north-south direction, in the same district. As this report covers 47 pages, and is easily accessible, only fragments of it will be quoted here.

In considering these alleged evidences of a local glacier in the valley of the Ottaquechee, let us commence at the heads of the two branches, in Plymouth and Sherburne, and proceed down the valley to its mouth at North Hartland. Inasmuch as the possibility of interpreting the features as records of the retreating continental ice sheet is sure to suggest itself to the critical reader, and is strengthened rather than weakened by observation in the field, at every point, we may profitably apply this alternative hypothesis, likewise, in turn, to each class of evidence.

SOUTHWEST BRANCH.

The more southerly branch of the Quechee glacier was conceived to have headed in the hollow east of Mt. Tom, in Plymouth, (see Pl. XIX), and to have extended northeastward down Pinney Hollow, to the main valley at Bridgewater Corner. The first criteria of local glaciation for which a physiographer of today would search, would be a U-shaped trough-like valley heading in a deep bowl-like basin or "cirque." Such forms are characteristic of valleys that have long been occupied by living glaciers, and of those alone. No attention whatever was given to such evidence by Edward Hitchcock or his son, who, like their contemporaries, with the possible exception of Agassiz, saw little or no significance in that sort of glacial record. The only allusion in the '61 report to the possible sculpturing activity of the Quechee glacier lies in the rather vague reference to rocky slopes scrubbed as if by ice moving from southwest to northeast.

Examining the hill-encircled basin at the head of Hollow Brook, in Plymouth, as it is shown in Plate XIX—a part of the recently published Woodstock Quadrangle, one looks in vain for cirque-like form. It is true that the basin is surrounded by well defined slopes but they do not compose themselves into a semicircular headwall like that, for instance, of King's Ravine near Mt. Washington, in the White Mountains. They are just such moderately steep, stream carved hillsides as one might find almost anywhere in the remote hill country of New England,—indented and irregular, but nowhere precipitous. Furthermore, the basin does not occupy a situation favorable for the catchment of snow and the nourishment of a valley glacier. There are no real mountains beside it, merely hills whose summits match the general upland level of this foothill district of the Green Mountains, standing only 2,000 to 2,200 feet above sea level and only 600 to 800 feet above the floor of the basin itself. There is no particular reason why a local glacier should have developed here unless

glaciers developed in all the valleys of the region. It would seem far more reasonable, for instance, to look for the head of this glacier among the higher summits of the Green Mountains, which lie only ten miles west of here, and approach or exceed 4,000 feet. The floor of this basin is not the rocky, glacier-worn floor of a cirque, but is cluttered with sandy kames and kame terraces, which, as the closed and scalloped contours of the map suggest, take the form of irregular swells, mounds, and rudimentary terraces. Moore's ponds, although largely artificial, occupy natural kettle holes in this kame field. The kames are so related to two notches in the western rim of the basin as to demonstrate that during the accumulation of the deposits the basin was occupied by a lake, blocked by the retiring ice sheet. At the extreme southwest corner of the basin, between Mt. Tom and a spur of Blueberry Hill is a notch in the rocky hillsides, through which a steep, disused road descends to the valley of the Black river. The head of this notch—which is locally known as the "old notch"—is only about a rod wide, and stands at an altitude of approximately 1,490 feet. In it is a small but clearly defined stream channel, now occupied by a shallow pool of water, half concealed by brush (see Plate XXb). Ledges outcrop in the walls on either side of this channel, just above its floor. Around the head of the notch, behind the pool, gently undulating kames make the present watershed. Not a sign of modern gullying is to be seen there, and there is no drainage through the gateway now except the insignificant amount which probably comes from melting snows near the pool, in the spring. Obviously, the notch and the little channel at its head were not cut by the present drainage, but by a more considerable stream. The situation leaves little room for doubt that this was the outlet of a lake which occupied the southern part of the basin. In support of this theory, one finds that the summits of the kames around Moore's ponds rise rather definitely to the level of the channel or spillway, but rarely exceed it, and show a distinct tendency, in places, to flatten at that height. Such is the case, for instance, along the old road between the Moore homestead and the spillway, as the contours of the quadrangle show.

A mile farther north, at the northwest corner of the basin, lies another gorge, known as Plymouth Notch. In its general appearance this closely resembles the more southerly notch; but its entrance is somewhat wider, with less precipitous sides, and the spillway channel in it is less distinct, owing in part to the construction of the grade of the state road beside it. The altitude of the ground at the head of this notch, according to the contours, is a little over 1,420,—say 1,425 feet. It is thus about 65 feet lower than the old notch. It is obvious that both notches could not have served at the same time as outlets of the glacial lake east of Mt. Tom. The more southerly one, inaugurated by the recession of the ice border, might serve as a spillway so long as the more northerly one remained blocked; but as soon as the melting ice uncovered the latter, the waters of the lake would have drained down from the 1,490 to the 1,425-foot level. That this indeed occurred is strongly suggested by the presence, at the more northern end of the basin, of a high flat kame terrace, with a typical esker-like projection, at 1,420 feet, and a more extensive plain, at the same height, at Plymouth Post Office (See Plates XIX and XXa).

Instead, therefore, of providing a characteristic glacial cirque for the head of a local glacier, the basin at Plymouth affords peculiarly clear evidence that upon the retirement of the continental glacier from the district, that basin was occupied by a temporary lake. Because of the significance of this lake, small and short-lived though it was, it is here proposed to call it glacial Lake Plymouth.

The form of the valley from Plymouth down through Pinney Hollow to Bridgewater Corner is even more difficult to reconcile with the theory of a local glacier. The contours of the Woodstock quadrangle (shown in Plate XIX) faithfully show it to be crooked, V-shaped ravine, whose width is proportional to the volume of the small torrent which now flows along its narrow rocky bed. The Ludlow road, passing along this valley, winds from side to side around a succession of alternating spurs, whose faces and flanks show outcropping ledges. The brook bends, in conformity to its valley, and has only a narrow flood plain, in favorable stretches where the valley opens out along the strike of the rocks. This character continues down to where this branch unites with others, in a wider, gravel-filled valley, near Bridgewater Corner. It is inconceivable that a local glacier should have passed down this valley, conforming to its crooked course, without cutting away the projecting ends of the overlapping spurs and converting the V-shaped gorge into a U-shaped trough. There are places in the gorge, above Pinney Hollow, where ledges of foliated schist, badly cracked by weathering along the joints rise in the middle of the narrow valley, forming obstacles which a local glacier would have wholly removed had such a glacier existed.

As regards the scrubbed surfaces of spurs and hillsides, near this branch of the Ottaquechee, the evidence given in the 1861 report, while none too clearly stated, can readily be explained as the work of the continental ice sheet. As one goes over these hills, which trend north and south, following the strike of the rocks, he finds that the ledges of non-resistant schists which outcrop plentifully along their crests and flanks have been severely scrubbed wherever they appear, whether on the southern or the northern slopes, or on the eastern or the western sides. Since the planes of weakness in the ledges generally follow the

PLATE XIX.

MAP OF PLYMOUTH AND VICINITY.
WOODSTOCK QUADRANGLE, U. S. G. S.

foliation and lie parallel to the direction of regional glaciation, there is very little tendency toward the development of characteristic unsymmetrical "rôches moutonnées," with "stoss" and "lee" sides; the effect is rather that of a completely "stossed" surface. It may be said, therefore, that such rounding as Edward Hitchcock called attention to is not in any way exceptional, in this district, whether it occurs on the southwestern sides of ledges and spurs, as he said, or on their northeastern sides. In fact, there is a prominent ledge just west of Bridgewater village, on a southward sloping hillside just above the river, whose surface is heavily scrubbed and rounded "as if by ice moving northward," *which would here be exactly at right angles to the course of the main Quechee glacier.*

At one point in the valley, just above where Pinney Hollow Brook joins that from Hale Hollow, a rocky spur shows rounded ledges which face up the branch already described. This might well be one of the worn ledges alluded to by Hitchock. It is possible to explain this condition either by ice-sheet erosion as has been done in the preceding paragraph, or as the work of torrents during the period of deglaciation; for above the ledges and extending to a considerable height, are rolled gravels massed into a kame terrace, and the basin-like depressions and protuberances of the worn rock surface are more suggestive of river work than of glaciation.

A significant bit of evidence indicating the direction of ice movement in the valley was discovered about a half mile south of Bridgewater Corner. A low ledge, here, stands beside the road, where the rocky side of the valley dips beneath the sand-filled bottom land or intervale. The ledge is an inclined rib of gray mica schist, reenforced by an eighteen-inch vein of quartz. The vein rises only five or six feet above the ground and dips northward into it at an angle of about thirty degrees. The northern side slopes gently with the dip; but the southern face is overhanging. The quartz vein at the top of the ledge bears striae which runs S. 30° W. (magnetic), or S. 17° W. (true). It is clear that the ice must have moved over it from north to south, and not from south to north; for while the former movement might allow the ice to over-ride it without destroying the ledge, a movement from the south, such as the local glacier was thought to have had would certainly have ripped off its projecting top. Inasmuch as the ledge lies almost at the bottom of the valley, it stands where local glaciation would have been vigorous. It is fair to conclude, therefore, that this ledge, like all others, was scrubbed and striated by the continental ice sheet, in its southward course.

A. ESKER AND OUTWASH PLAIN NEAR PLYMOUTH.

B. ENTRANCE TO THE "OLD NOTCH," PLYMOUTH.

WEST BRANCH.

The larger branch of the Ottaquechee valley, which heads in Sherburne, east of Killington and Pico peaks (see Plate XVII) might be expected to afford better evidence of local ice movement. As shown on the Rutland sheet of the U. S. Geological Survey, this upper part of this valley above West Bridgewater, is distinctly trough-like. For over six miles, it follows a straight course, with precipitous walls rising on either side to a height of from 800 to 1,500 feet above its level floor. It is noteworthy, however, that the cross section is that of a river carved V-valley, whose bottom has been filled up by floodplain or outwash deposits rather than that of a glacier-sculptured U-trough. No rock shows on the flat floor, and there are no sudden step-like breaks of grade such as a glacier trough exhibits. The valley sides, also, do not present the truncated spurs characteristic of river valleys which have been widened and straightened by local glaciation. The unusual straightness of this section of the valley would seem, therefore, to be due to some other factor. That factor is found in the presence of a belt of limestone, which outcrops all the way along the valley (and along its continuation in the Black river valley of Plymouth and Ludlow), on the eastern side of the Green Mountain anticline. Where this lime stone belt is straight, as in Sherburne, the valley is straight and trough-like; where it bends around a cross fold, as in Plymouth, near Blueberry Mountain, the valley bends, in obedience to structure, as Hager clearly stated and showed in his geological map of Plymouth in the 1861 report.[1] The straightness and the trough-like cross section of the Sherburne valley, therefore, cannot be used as evidence of the presence of a former Quechee glacier.

That glaciation cannot have carved this valley is even more plainly seen when one examines the continuation of it between West Bridgewater and Bridgewater Corner. At West Bridgewater (on the Sherburne town line) the river leaves the limestone valley and turns eastward across a wide belt of talcose and mica schists, in which it has cut a crooked gorge of great depth. The objections already raised to local glaciation in the southwest branch in Pinney Hollow apply with still greater force here. The succession of overlapping spurs, the narrow, canyon-like cross section, and the utter absence of any sign of glacial widening, afford little ground for the theory of a local glacier. The characteristics are typical of rapid erosion by a torrential river running transverse to the strike of the rocks.

MAIN VALLEY FROM BRIDGEWATER CORNER TO WOODSTOCK.

At Bridgewater Corners the two branches of the Ottaquechee meet in a V-valley of greater width, appropriate to the volume of

[1] Op. cit., vol. 2, Plate xviii.

the river. The rocky floor is deeply buried beneath the modern floodplain which the river has carved from an outwash filling of greater height. At short intervals, on either side, along the valley, banks or mounds of stratified drift lie against the valley sides or less commonly rise from the floor itself. Among these deposits are the "terminal moraines" reported by Hitchcock. In the more flaring form of the V-shaped valley there is reason to dissent from the theory of a local glacier. As regards the moraine-like mounds, it is at least fair to test the theory that they are kames built by the receding ice sheet.

Direct evidence of the course of local glacial movement, in the shape of iceworn ledges and grooves, are not as plentiful as might be wished, by one seeking to prove or disprove the theory of local glaciation. Hitchcock himself had no local striae to report, but he recorded observations which established the general course of the "drift agency" or ice sheet, on the hills of the region, as aiming slightly west of south. It has not seemed worth while, therefore, to make particular search for local glacial striae in the Ottaquechee valley; yet one locality, at least, has been found, where the course of the ice definitely contradicts the theory of a local glacier and supports the theory of a regional ice cap. This is on the heavily glaciated ledge just west of Bridgewater, already mentioned. Quartz veins here, at a height scarcely 25 feet above the river, are striated somewhat obscurely in a direction S. 40° W. (magnetic) or S. 27° W. (true). This direction is approximately parallel to that noted by all observers as the course of regional glaciation.

It is unnecessary to enumerate in detail all the deposits of stratified drift which may be seen, in passing down this valley. Mention need be made only of those which have drawn the attention of Vermont geologists, or which, because of some clear significance, seem worthy of attention.

At Bridgewater Corners, on the south side of the river is a short kame ridge or rudimentary esker, which extends, with some interruption, from the sawmill on the west side of the Ludlow road eastward to the confluence of the two branches of the river, where a monument marks its crest. The altitude of this esker is approximately 870 feet. The village of Bridgewater Corners itself stands on a narrow, terraced shelf of gravel which appears to be a kame terrace, at an altitude of about 880 feet. On the south side of the valley, opposite Bridgewater village are several irregular kame mounds and one esker-like kame ridge, which the 880-foot contour on the Woodstock quadrangle suggests. This ridge extends eastward nearly to the dam. Beyond it, near the mouth of Curtis Hollow, are flattish kame mounds, banked against the side of the valley, which suggest a terrace deposit formed by the outwash of sediment between a tongue of ice and the hillside (see Plate XXIIa). On the north side of the valley, here, immedi-

PLATE XXI.

PLYMOUTH NOTCH.

ately east of the village, stratified gravels and sands form a wide plain, at the 840 contour, where A. R. Weeden's baseball grounds are located; and behind this are higher gravel terraces. One is shown in Plate XXIIb. This extensive group of kame terraces and kames seems to constitute the "still more decided example of a terminal moraine" which Edward Hitchcock compared to the local moraines of Savoy, but recognized as having suffered greater "modification by water." One looks in vain for any sign of a crescentic ridge of unassorted, ice-laid drift, or for any other characteristic slope which might mark the outline of the lower end of a local glacier in the valley.

Passing other, smaller kame mounds and scraps of kame terraces, one reaches the "lateral moraine" described by Charles Hitchcock, near an iron bridge, where bench mark 773 is shown on the government map. Here, on the north side of the river, is a high bank of till, strewn with an unusually large number of angular blocks of the native rock. It might well be explained as a thick mass of ground moraine which has been shaved away by the river at a time when it ran on a terrace at the level of the road. The boulder strewn slope is striking, indeed; but there is no occasion to invoke a local glacier to account for it. There is no definite ridge-like form of ground, there, such as a typical lateral moraine would possess. In short, to the present writer, the theory of local glaciation, if not unwarranted, seems entirely unnecessary.

The "moraine just east of a broad area of low ground"[1] at West Woodstock, mentioned by Charles Hitchcock, is probably the drift deposit at the cemetery. This, like the "moraine" of modified drift at Bridgewater lacks the form and structure of a moraine of the alpine type; it may, however, be interpreted as a remnant of an extensive outwash terrace, whose flat top stands at approximately 800 feet. Its existence may be accounted for by the accumulation of river washed sands and gravels in the valley, during the retreat of the continental ice sheet. Since the valley narrows considerably, just east of this point, the river, confined here by ledges, has had less opportunity to swing from side to side, and destroy the terrace than on the wider stretch to the west, where the terrace is less well preserved.

MAIN VALLEY BELOW WOODSTOCK.

This lowest section of the valley affords perhaps the most interesting collection of glacial and fluviatile features, from among which Professor Hitchcock, nine years ago, selected a number of evidences, as they seemed to him, of a former local glacier. The course of the valley below Woodstock is more crooked than that above. For several miles the river runs due eastward, as if it

[1] Hitchcock, C. H., Op. cit., p. 181.

would join the White river (see Plate XVII); but half a mile below Quechee it turns sharply southward, and passing through a long gorge of extraordinary depth and wildness, known as Quechee Gulf, flows out along a wide open valley, with a southeasterly course, to join the Connecticut river at North Hartland. Plate XXIII shows this in detail. Whether the Ottaquechee did actually join the White river, in preglacial time, is not yet known; but its course at the Gulf, immediately below the bend, is almost certainly post-glacial in detail if not in its entirety. The gorge is a mere slit, one hundred feet deep, half a mile long, and scarcely wider at the top than at the bottom, where, at high water, the river completely covers its rocky floor. Falls occur at the head of the gulf, at Dewey's Mills, and rapids with pot-holes lie all along the bed of the stream. The rapid vertical intrenchment of the river in the rock may be attributed chiefly to the weak, fissile character of the schists, along the strike of which the gorge has been cut, and partly, perhaps to the originally steep slope of the surface of the rock barrier down through which the gorge has been sawed. If the river formerly passed southward to the Connecticut at a point farther east than this gorge, there is no sign of its buried valley.

The Dewey's Mills Delta.—Next to the picturesque gorge the most conspicuous feature of the valley is the high level plain or plateau of sands which Professor Charles Hitchcock interpreted as an apron, washed out from the front of a local glacier while it rested, during its retreat, near Dewey's Mills. The report does not make it clear whether he regarded the plain as a delta, built in static water, or as an alluvial fan, built above water level, but states that the deposit "occupies just the position of a terminal moraine." Its altitude, according to the contours of the Hanover quadrangle, is 640 feet (see Plate XXIII). This thick sand deposit, originally stretching continuously across the valley, is conceived to have acted as a barrier to the waters of the Ottaquechee, damming that river up to form a lake, which expanded up the valley as the ice sheet withdrew, and which lasted until the overflow, working on the lowest line available, had excavated the present chasm. A rude esker-like ridge of gravel is noted, on the divide just west of the Gulf. The ground below the overwash plain, for half a mile, is described as "partly of ledge and partly morainic," showing "that there is an abrupt change in the character of the materials."[1]

It is the opinion of the present writer that this plain has a different significance from that which Professor Hitchcock attached to it. Two facts, in particular, make it of unusual interest: first, the remarkably flat surface, at an altitude (650 feet) which corresponds very closely with that of certain deltas in the

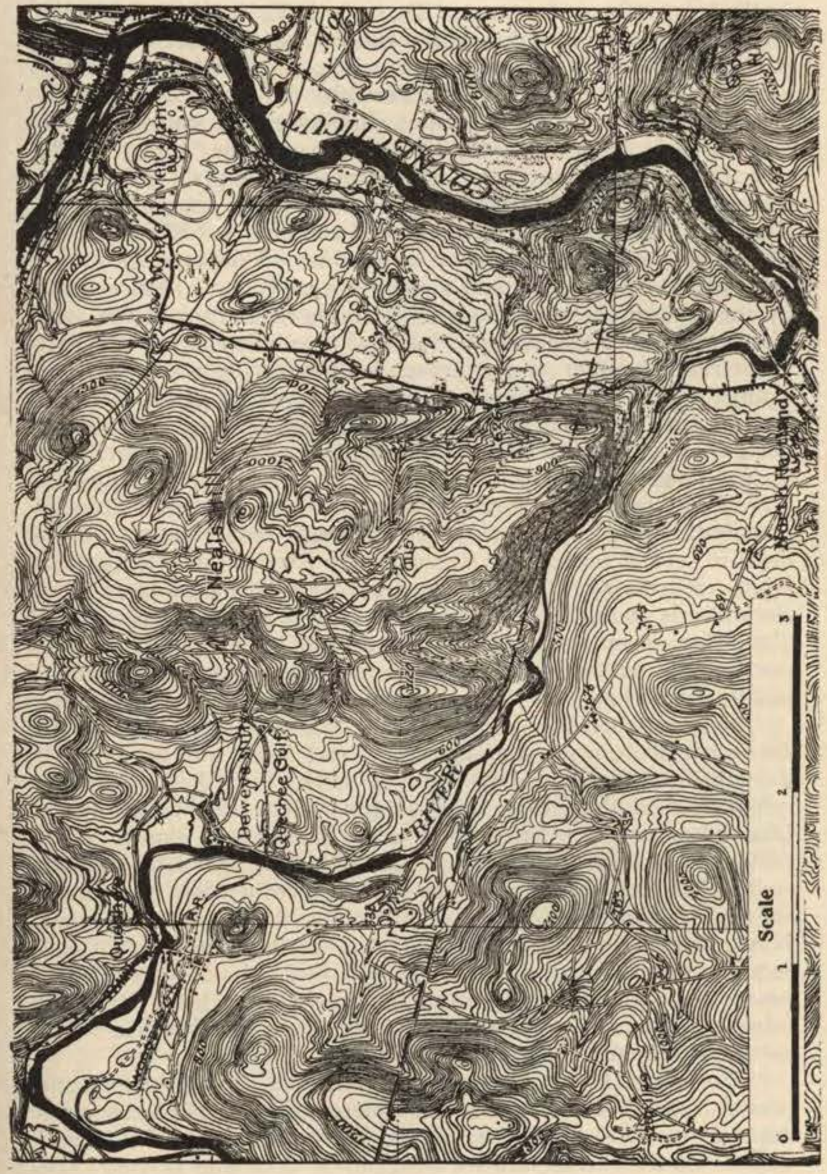
[1] Hitchcock, C. H., Op. cit., p. 182.

PLATE XXII.

A. KAME TERRACES SOUTH OF BRIDGEWATER

B. TERRACE EAST OF BRIDGEWATER.

PLATE XXIII.



MAP OF THE OTTAQUECHEE VALLEY BELOW WOODSTOCK.

Connecticut valley elsewhere in the Hanover quadrangle (at Norwich and at Hanover); and secondly, the marked delta structure in the long railway cut east of Dewey's Mills station. Although too badly blurred by talus at the time of preparation of this report to make a photograph worth while, this cut has previously exhibited in fresh section, a beautifully arranged series of inclined "foreset" beds of fine sand, dipping gently southeastward, and overlain by a few feet of coarser gravelly "topset" beds, which make the flat surface. The flatness of the plain is in reality more striking than one would suspect from the contours of the Geological Survey map; for the closed contours at 640 feet, north of the railway, delineate minor inequalities of slope which are of very slight consequence, and might reasonably have been ignored by the topographer. Although the southern margin of the sand plain lacks the well developed lobes of a complete delta, this may be attributed either to the presence of lingering masses of ice, against which the sands were washed, or to post-glacial erosion. In a pasture just south of the station, ledges outcrop on a steeply descending slope with channel like swales and hollows distributed in such a way as to strongly suggest that before the Ottaquechee river found permanent location along the line of the Gulf, it or its distributaries worked down over the steep outer margin of the delta in several places, and washed away part of the soft material which composes it. The northern border of the sand plain, near the mills, is characterized by sags and swells, such as are usually along the ice contacts of pro-glacial deltas. There is no apparent decrease in coarseness of gravel from this ice-contact southward; but this is perhaps not a vital objection to accepting it as a delta.

Instead, therefore, of regarding this deposit merely as an overwash plain, banked up against the ice front, and by its rapid growth blocking the valley, we may rather regard it as a delta, constructed at the ice-front by streams which discharged into a lake whose extinct surface or water-plane now stands about 640-650 feet above the level of the sea. That this lake was not confined to the lower valley of the Ottaquechee but overspread the Connecticut and its larger tributaries, as far north as Hanover, if not farther, is indicated by the presence there and in Norwich as already mentioned, of other 640-650-foot deltas. We shall see, presently, that this interpretation is borne out by a study of other kame terraces and kames farther down the Quechee valley even to its mouth, near the Connecticut.

Professor Hitchcock has not indicated in his report any reasons why this sand plain should be considered as the terminal deposit of a local glacier of the alpine type instead of the frontal deposit of the continental ice sheet, or of a tongue of that sheet lying in the valley of the Ottaquechee. If the writer has not been mistaken, in discussions with him, one of the chief reasons he relies upon is the semicircular form of certain well developed

escarpments, in the terraces behind the sand plain,—escarpments which he interprets as banks built up against the semicircular margin of the local glacier during its spasmodic retreats from the overwash plain. In the opinion of the writer, these curved terrace scarps are river-carved banks, and have no relation to the form of an ice margin in the Quechee valley. It is thus possible to regard the sand plain as an outwashed delta, constructed at the front of the continental ice sheet in the deep ponded waters of the Connecticut.

Terraces of the Quechee "glacial lake."—In his 1908 report Professor Hitchcock mentioned and illustrated with maps and photographs, a number of extensive terraces of sand and gravel in the valley above Dewey's Mills plain. These he took to be signs of the former extent of "Quechee glacial lake,"—the body of water which was held in by the newly constructed morainic apron on the south, and bathed the retiring ice front on the northwest and west. The number of terraces is said to vary, being five in one place where they are well developed, and six in another. Although no actual measurements are recorded, the flights of terraces at different places "are believed to agree in altitude." "There has been no attempt as yet to show the causes acting for the formation of each terrace. They were probably connected with variable ice barriers."[1]

The ambiguity of this statement makes it necessary for us to invent a theory to account definitely for the curved scarps and terrace flights. If we assume that the scarps are wave cut cliffs, carved during repeated halts of a subsiding lake level, we encounter the difficulty that wave action in this sheltered valley could not develop strong sea cliffs and wide platforms of the size of these scarps and terraces. We might suppose, however, that the curved scarps mark successive positions of the curved edge of the glacier, and that the flat terrace tops are records of successively lower and lower lake levels for each stage of ice front so recorded. This, so far as the writer gathered from Professor Hitchcock, is the interpretation which he would give the terraces.

A careful study of the contours of the Hanover quadrangle suggests for the terraces at Quechee the interpretation given by Professor W. M. Davis to valley terraces generally in New England. River sculpture, carried on where ledges are frequently encountered beneath a filling of drift, is entirely competent to explain them. It will be noticed that the two places where the longest flights of terraces exist, one of them a little over a mile above Quechee, and the other a half mile east of that village, lie on the inner side of two bends of the river. In each place, the river has been pushing outward towards its north bank, while it carved away the soft outwash which originally filled the

[1] Hitchcock, C. H., Op. cit., pp. 182-183.

valley. The best terrace flights therefore are situated just where they would be most likely to escape destruction by river cutting, lying on the "safe side" of the river. On visiting the more westerly flight of terraces, however, one finds that the preservation of them there is due not wholly to favorable situation, but in part to the presence of ledges which the river has struck, during its down cutting, which have prevented the continuance of lateral planation at or above the level of the outcrop. Clearly defined channels, long ago deserted by the river, appear at the foot of these terrace scarps, tangent to the protective ledges. I am therefore led to conclude that the terraces have no relation to an extinct lake but have resulted from the excavation of a 650-foot outwash plain by the river.

The terrace flight east of Quechee may be attributed, similarly, to river erosion. The most interesting terrace in the group occurs on the north side of the river, just north of Dewey's Mills (see Plate XXIII). The road to Quechee, here, makes a long semi-circular detour on the terrace top, to keep above the level of the modern floodplain. The curved 30-foot escarpment which separates the terrace from the modern floodplain is neatly shown on the Hanover quadrangle, together with a well defined meander scar which runs around the outer border of the floodplain near the foot of the scarp. Though long since deserted by the Ottaquechee river, this scar serves as the path for the discharge of three small tributary brooks. The upper border of the terrace is a steep curved bank similar to the one at its lower border, and near the foot of this bank is a stream channel, which follows a curved path, crossing the road at the corner where bench mark "542" is shown and again near a small brook a few hundred yards west of that place. A lower terrace than this one, characterized by a similar curved depression or meander scar, occurs just southeast of the road corner, near Dewey's Mills. The contours of the government map do not do justice to this feature. In view of the typical curvature of the scarps, and the association with them of abandoned stream channels or meander scars, it seems unreasonable to ascribe them to any other agency than river sculpture. One of the chief evidences of the "Quechee local glacier" presented by Professor Hitchcock may thus be abandoned. It may be remarked that in the same report this investigator attributed certain terraces at Hartford, on the White river, to river erosion, although the scarps and meander scars on them are less characteristic in their curvature than those at Quechee.

Quechee esker.—The esker which Professor Hitchcock employs as evidence of a local Quechee glacier lies close beside the more westerly of the terraced outwash remnants just mentioned, in the northwest corner of the map, Plate XXIII. It might indeed almost be said to be a part of the terrace, for the ridge and the plain rise to a common level, and the hollow between them is only

one or two hundred feet wide. The esker is by no means a typical one, but like that at Bridgewater Corner and the one south of Bridgewater village is a short ridge which rises steadily for seventy-five yards or so and spreads at the 660-foot level into a flat summit of elliptical plan (see Plate XXIVa). Just beyond, or at its southeastern end, it stops abruptly near a farm road, as suggested by the contours of the Hanover quadrangle. A maple tree on its crest, which Professor Hitchcock mentioned, makes a good landmark.

Professor Hitchcock did not consider the possibility that this esker marks the course of a river within the *continental ice sheet*. He accepted it without hesitation as "a small typical esker .... which must have been made either in the archway near the end of a local glacier or in an open cut. Therefore, there must have been a local glacier sliding down the valley below Woodstock."[1] As is well known, eskers occur by the hundred, and in all parts of New England, including such low coastal districts as that around Boston, Massachusetts, where no one has ever thought of attributing them to *local* glaciers, but all investigators have attributed them to rivers within the *continental ice sheet*. Why should this esker near Quechee be regarded in any different light? A river discharging through a tunnel or canyon at the front of the melting ice sheet is an adequate explanation. The extensive sand plain beside the esker may have accumulated at the same time, in that part of the valley just beyond the ice margin, either in what was then the westernmost corner of the pro-glacial lake of the Connecticut valley or in a marginal river discharging past the ice into that lake. As the altitude, judging from the contours, is 10 or 20 feet higher than of the Dewey's Mills plain, the latter interpretation seems the more likely to be true. Towards the south this 660-foot terrace rises, past the deep railway cut, and culminates in kames which flatten just above the 680-foot contour. These extend eastward along the road, as if under the control of a spillway through the flattish saddle that lies due south of Quechee village, and west of the 920-foot hill (see Plate XXIII). The ground on the summit of this saddle is shown as slightly over 680 feet; and although no clearly defined spillway channel appears in its bottom, it is true, as Professor Hitchcock pointed out, that sandy kames appear on the other side of the saddle, at 660 feet, southwest of the Gulf, and continue interruptedly for some distance down the valley. The whole group of kame deposits at the railway curve west of Quechee may therefore mark the course of ice marginal drainage into the ponded waters of the Connecticut valley either (a) at a time when a tongue of ice still blocked the path east of the 920-foot hill and the gap west of that hill served the purpose, or (b) at a time when

[1] Hitchcock, C. H., Op. cit., p. 181.

the melting ice had withdrawn just far enough from the east side of hill 920 to let a small lake in the Quechee valley discharge across the rocky ground west of Quechee Gulf at a height just above that of the lake in which the Dewey's Mills plain was built. Either condition might arise during the uncovering of the valley by the continental ice sheet.

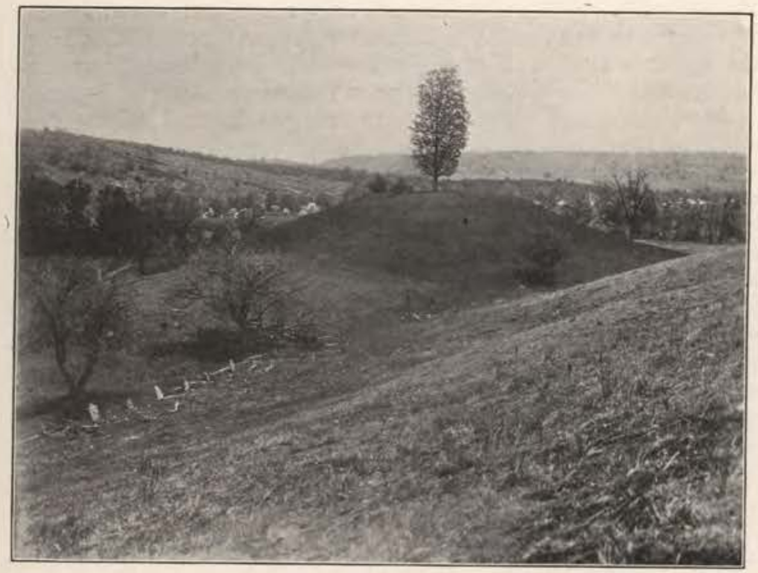
Kame deposits below Dewey's Mills.—Professor Hitchcock reported that "about a mile below this conceived outlet (west of hill 920) there commences a thick deposit of modified drift continuous from schoolhouse 22 to North Hartland. These high terraces are connected only with the spillway, not with the river in the gorge."[1] This train of terraces he mapped in Plate xxiv of his report, with generalization, as "modified drift." They constitute one of his reasons for believing that at a stage earlier than that recorded by the Dewey's Mills plain the Quechee local glacier extended down to North Hartland.

In a traverse of the district concerned, the writer was surprised to find that this line of kame terraces is very discontinuous. For the first half mile below the 680-foot spillway, kames, built against the hillsides overlooking the Ottaquechee valley show a strong tendency to flatten at an upper limit of 660 feet. Lobate projections of the 660-foot contour on Plate XXIII indicate that this fact did not escape the attention of the topographer of the Hanover quadrangle. The kames descend, however, with sprawling branching form to levels one hundred feet below that and at one point just north of the first brook, near the town line, a conspicuous table-like remnant or bank of sand marks a 540-foot level (Plate XXIVb). The upper limit of the lateral drainage marked by kames at 660 feet agrees reasonably well with the idea that a 640-650-foot level of static waters replaced the ice sheet. The lower flats seem to be remnants left by wholesale erosion of a once continuous valley filling. Farther down the valley, just west of Harlow Brook, even topped, sandy kames draw attention to the 560-foot level. The meaning of this is not clear. Elsewhere in the Hanover quadrangle, particularly at Hanover, are much plainer indications of a 560-foot stage of the lake which occupied the Connecticut valley, occurring, it seems, after the 640-foot stage. It is hard to see how the 560-foot kames near Harlow Brook could mark that stage, since the 640-foot plain of Dewey's Mills lies two miles farther up the valley. Possibly remnants of ice occupied the middle of the valley below the Gulf, even after the 640-foot stage had given way to the lower, 560-foot stage, and local accumulations of sediment were filled against these ice masses at the lower lake level.

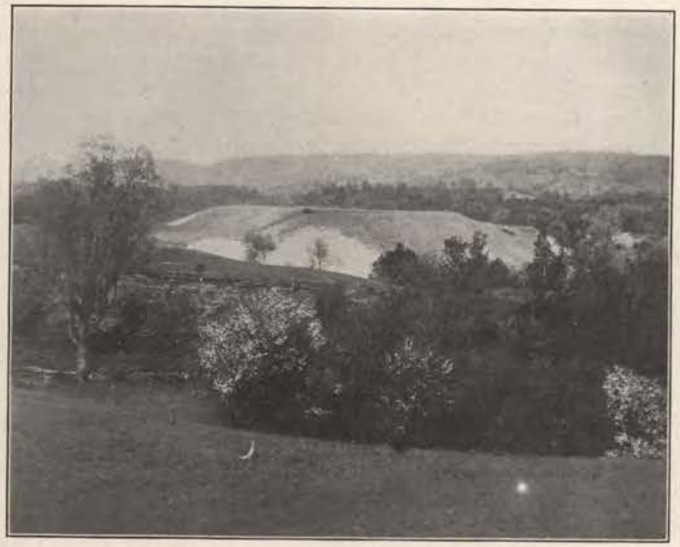
The statement concerning continuity of sand deposits below schoolhouse 22 needs correction and amplification, to be better

[1] Hitchcock, C. H., Op. cit., p. 182.

PLATE XXIV.



A. QUECHEE ESKER.



B. SAND PLAIN SOUTH OF QUECHEE GULF.
540 FEET ELEVATION.

understood. On the hillside up which the road goes, from the "676" corner, at the schoolhouse, to a summit point at "745" feet, only ground moraine and ledges appear; but at this height of land a flattish bank of coarse, cobby drift suddenly appears and with gentle yet steady slope spreads eastward and southeastward, in fan-like fashion, to the level of about 640-620, where it flattens in cultivated fields with broad lobes. At its summit this fan is marked by a distinct, curved stream channel, which crosses the road between two farmhouses. It has every appearance of being the deposit and channel of a stream flowing eastward from the ponded basin of Harlow Brook while the ice sheet still blocked the valley of the Ottaquechee between Quechee Gulf and North Hartland, with its margin resting against the northern side of the hill east of the schoolhouse. The rather abrupt head of this fan at the 740-foot level seems impossible to explain in any other way, and the continuous descent of the deposit eastward to the lobate margin at 640 feet correlates it with the static waters of the Connecticut valley recorded so plainly at Dewey's Mills, and near Hanover.

From this point eastward to North Hartland extensive sandy kames are crossed by the road. How far the irregularity of surface of these deep clay and sand deposits is original, and due to masses of ice lingering while the deposit accumulated, and how far the irregularity of surface is the result of subsequent erosion by streams tributary to the Connecticut is difficult to determine. There are certainly slopes of both sorts. Among those surely constructional and original are the slopes of a conspicuous ridge, near the bluff of the Connecticut River overlooking Hartland, where a well developed esker, built of coarse gravel, runs for fully a quarter of a mile in a north-south course. This esker escaped the attention of those who mapped the "modified drift" in the State Survey of New Hampshire, under Professor Hitchcock, in the '70's. It was perhaps a branch of the long Connecticut esker, which runs from North Thetford to Windsor.

Glacier-worn ledges.—Finally, Professor Hitchcock says:

"There is some further evidence of the glacier's passage south of the Gulf. The striae on the rocks half a mile south of the railroad run S. 13° E., and upon the precipitous side of a large hill (1120), southwest from Neal's Hill there is apparent a glacial smoothing facing the river, which must have been made when the ice slid down the valley before the formation of the barrier at Quechee Gulf. In the old days these glaciated walls were cited as evidences of glacial in distinction from iceberg action."[1]

While the glacial smoothing and the striae referred to might have been made by a local glacier, it is also obvious that they might have been made by the continental ice sheet; for the course

[1] Hitchcock, C. H., Op. cit., p. 182.

of the striae is not only parallel to the valley but is also approximately parallel to striae on neighboring hilltops, where the ice sheet is the undisputed agency responsible for them. On the summit of hill 920, for instance, southwest of Dewey's Mills, are striae, on quartz veins, running S. 8° E. (true); and in many other parts of the Hanover quadrangle, striae have been observed, as Professor Hitchcock's report abundantly records, which show the ice sheet to have had a nearly due southward course. The mere fact that the ledges in question occur in the valley favors one theory not a bit more than the other. We may therefore discard this evidence of a local glacier, like that discussed on the foregoing pages, and attribute it, like the rest, to the continental ice sheet.

BLACK RIVER LOCAL GLACIER.

The evidence of the former existence of a local glacier in the valley of the Black River is thus set forth in the report of 1861, by Edward Hitchcock. (Refer to Plate XVII for location).

"Black River takes its rise in the northwest part of Plymouth, near the head of a branch of the Quechee. Black River runs south through the whole of Plymouth, and to the middle of Ludlow, where it turns easterly through Cavendish, Weathersfield, and Springfield, to the Connecticut. Between Ludlow and Proctorsville, say a mile and a half east of Ludlow, on the north side of the road, a rock is exposed, a little more than a rod in length and only four or five feet high, on whose top are developed two sets of drift striae; one—the most distinct—running N. 2° E. by the needle, and the other N. 50° E. But on the perpendicular face of the rock is another set of striae, running in the direction of the valley, namely, N. 50° W. and S. 50° E., as shown on the sketch below (Fig. 33). It seems impossible to account for these striae, especially the last named, without supposing a glacier once to have descended the valley, which, however, has a very gentle slope. In following the valley northerly we meet with no other sign of a glacier till we reach the long pond in Plymouth, say eight miles north of Ludlow. This pond is long and narrow, and towards its north end is entirely divided by a mass of detritus of sand, gravel, and boulders, having exactly the appearance of the terminal moraine of a glacier. The shores of the pond elsewhere are remarkably free from detritus, and this causeway, over which a road passes, is only a few rods wide. The valley is narrow and the sides quite steep. If this was not the moraine of a glacier, we can hardly hope to convince the public that there are any in Vermont."[1]

"Black River passes into, and helps to form Plymouth Ponds —two beautiful sheets of water each of which is about one mile in

[1] Hitchcock, Edward, and others, Op. cit., vol. 1, p. 86.

length. Between these ponds there is a conical hill, composed of gravel and numerous water-worn rocks and small boulders. It appears to be unmodified drift, and doubtless is a terminal moraine, left there during the glacial epoch. A view of these ponds and intervening moraine may be seen in Plate xxxviii."[1]

Before considering closely the nature of this extraordinary "moraine," it is well to get a picture of the upper portion of the Black River valley, from which the local glacier was supposed to have come. This is shown on two contour maps of the Geological Survey,—Rutland Sheet, mapped in 1888-91 and Woodstock Quadrangle, mapped in 1910-1912. A photograph of it appears in Plate XVIIIb. From its head, in the northwest part of the town of Plymouth, southward to the "moraine" at Plymouth Ponds is a distance of five or six miles. Unfortunately, Plymouth Ponds and the remarkable "moraine" lie over a mile south of the southern margin of the Woodstock Quadrangle. The north-south valley of Black River is a direct continuation of the limestone valley of the Ottaquechee near Sherburne. The modern drainage divide, in this valley, is between Plymouth Pond or "Woodward's Reservoir and Black Pond,—headwaters respectively, of the Ottaquechee and Black rivers. The valley here is rather wide, its sides are very steep, and its floor is flat. Outcropping ledges of limestone indicate that between the lakes there is no great thickness of glacial gravels, although kames and kame terraces occur both north and south of the divide and are so nearly continuous that they appear to mark the path of southward flowing glacial drainage.

There is not the least suggestion in the form of the valley itself that a local glacier ever headed there. Streams entering from the east and west come down off the foothills and main range of the Green Mountains in crooked valleys, which narrow and open out headwards, terminating obscurely on graded mountain sides. One looks in vain for a possible gathering ground which would nourish a glacier in this particular valley. The hollows on the sides of Shrewsbury Peak (3737 feet above sea level), where the uppermost tributaries of Black Brook has its origin are open, graded depressions which lack the bold outlines of glacier-carved ravines. Similar slopes around the Killington Peaks, a few miles to the northwest, feed the headwaters of the Ottaquechee River. So far as one may judge from the headwater region, therefore, the Black River valley was not favorably situated for the maintenance of a local glacier.

At the northern end of Woodward's Reservoir, over a mile north of the Quechee-Black River divide, but at approximately the same altitude, an esker runs out into the lake, forming a peninsula

[1] Hager, A. D., Brief report on the geology of Plymouth, in Geology of Vermont, vol. 2, pp. 731-732, 1861.

over a quarter of a mile long and only a few hundred feet wide. It seems to head in a kame terrace, on the east side of the valley at the extreme northern end of the pond. Like hundreds of others in northern New England, this esker doubtless marks the course of southward flowing stream during the melting away of the great ice sheet from the valley. Less continuous mounds of gravel occur on the western side of the pond. A few hundred yards south of this pond, at the drainage divide, the floor is flattish and thinly drift covered. Beyond, at Black Pond, low outwash terraces appear on both east and west sides. These continue with frequent but short interruptions down the valley past Plymouth Union to the two ponds where the "terminal moraine" stands. The steep banks that form the faces of these terraces appear to have developed in contact with a lingering tongue of ice in the valley; for they have irregular knobby spurs such as might mark irregularities of the ice border. If the terraces were remnants of an originally complete valley filling, the escarpments, developed by river erosion, would be limited below by meander scars or other channels of the extinct river,—which seems not to be the case.

An extensive terrace of this character occupies the center and east side of the valley at Kirk Derby's, a mile above Plymouth Union, close to the edge of the Woodstock Quadrangle as shown in Plate XIX. Its top is about 50 feet above the modern flood plain. This is approximately the height of the narrower terraces at the Union. For a mile beyond the Union, no terrace appears at the foot of the precipitous side of Mt. Tom; but a short distance below the "old notch," where the valley passes Blueberry Mountain Hill, a terrace is again conspicuous on both east and west sides at a height of over 60 feet. Excavations for road material in it exhibit the usual stratified sands and gravels. From the west terrace an esker-like ridge extends obliquely towards the middle of the valley, just west of the "1154"-foot road corner. Half a mile farther south the esker habit is repeated, but this time on the eastern side of the valley, extending from the "Frog City" schoolhouse southward for half a mile along the Ludlow road, and passing beyond the edge of the Woodstock Quadrangle. Kames of linear habit occur on either or both sides of the river from here on, in the next mile, reaching the north end of Plymouth Ponds as a strongly developed esker, which the highway skirts and then crosses, as it meets the shore of the lake. Down the eastern side of this lake, a continuous kame terrace shows in cleared fields against the valley side. The old "military road" shown on Plate XVII follows it. Along the western side, close to the Ludlow road, a similar terrace is concealed by forest, but its cobbly structure shows in roadside borrow pits. Thus the broken but well organized line of kames extends from the upper waters of the Ottaquechee over the divide and down the course of Black River

to the point where the alleged moraine stands. Indeed, on the colored map by Charles Hitchcock illustrating the Surface Geology of Vermont, in the 1861 report, an unbroken line of "moraine terraces" is shown along the Black River as far as this point. Of it Hitchcock says:

"There are very few (river) terraces north of Plymouth Pond. The valley is mostly filled with moraine terraces and glacial moraines. There is good opportunity to examine the structure of such small terraces as are found upon mountain torrents, at the gold washings east of Plymouth Pond."[1]

The lithograph Plate XXXVIII of the 1861 report clearly shows the eastside kame terrace, as well as the conical mound or "terminal moraine" in the center of the valley.

As Hager said, in the 1861 report, the "terminal moraine" that lies between the two ponds is not a line of hillocks nor a ridge transverse to the valley, as a local moraine should be, but "a conical hill, composed of gravel and numerous water-worn boulders." It is an irregular oval, 50 feet high, with its long axis trending north and south, or longitudinally with respect to the valley. On its west side is a much lower, flatter hillock of drift, well sprinkled with boulders. On its eastern side is a gap cut by the outlet of the upper lake, over which a wooden bridge passes to reach the lateral outwash terrace already mentioned. The north end of the knob has been excavated, giving a complete cross section of triangular form by the side of "Interlaken road." Although too obscure to exhibit distinct stratification, because of caving of the deposit of the time of my visit, the contents are wholly water-worn material, and stratification doubtless exists. Among the rounded boulders are many over three feet in diameter, and thousands of cobbles. The material resembles that commonly seen in large eskers and kames of the Connecticut valley.

Aside from the fact that this knob, with its irregular, low wing-like appendages of drift stretches across the valley between the two lakes, there is nothing to suggest that it is a local terminal moraine. Certainly it is an error to say that it "has exactly the appearance of a terminal moraine of a glacier." It is not composed of ice-laid material, but of water-rolled and water-laid material; the trend of it is longitudinal rather than transverse, like an esker instead of a terminal morainic mound; and the occurrence of similar but more truly esker-like kames at frequent intervals up the valley, as already described favors the view that all are of one origin. So long as eskers and kames are attributed to escaping waters of the continental ice sheet, there will be no

[1] Hitchcock, C. H., in section on "Phenomena of Modified Drift," in the 1861 report, Op. cit., p. 121.

reason to accept this "moraine" of the 1861 report as evidence of an extinct Black River glacier.

Edward Hitchcock found "no other signs of a glacier" from this point down the Black River valley for nearly ten miles; there, between Ludlow and Proctorsville, as described in the quotation already made, he discovered the ledge with three sets of striae, one of which he felt compelled to attribute to a local glacier. Concerning the value of this evidence, it is perhaps enough to say that two or more sets of striae are not uncommonly observed elsewhere in Vermont and New Hampshire, and that in those cases where all the circumstances have been studied, in recent years, both or all sets have been assigned to glaciation by the ice sheet at two or more stages of transgression. I have not seen the particular ledge in question.

"LOCAL GLACIERS" OF THE MIDDLEBURY AND WHITE RIVER VALLEYS.

In his report of 1860, Edward Hitchcock gave especial emphasis to evidences of ice movement at the uppermost portions of the valleys of the Middlebury and White Rivers, in Ripton and Hancock, respectively. The evidence consisted in the main of striae which conformed to the courses of these valleys, on opposite sides of the range. Half a mile down the west side of the range, near the head of the Middlebury River, in Ripton, ledges were discovered which bore two sets of striae: one running S. 50° E. and the other S. 60° W. The former appeared to be "drift" striae, running uphill; but the latter were judged to be local glacier striae, running down the valley. Across the range, on its east side, in Hancock, ledges were found in the valley of the West Branch of the White River, running nearly due eastward, parallel to the river (with the stoss sides on the west); while farther down the White River, where its course is southward, striae, likewise, were found running southward. This conformity of striae with the course of the valley was considered by Edward Hitchcock to be good evidence that the marks had been left by a system of valley glaciers, "although the course does not differ much from some examples of drift in the same region upon the hills."[1]

As the writer has not visited the localities in Ripton and Hancock the discussion of this evidence is necessarily brief, and general. As stated on a foregoing page, divergent systems of striae, though so strange as to excite much speculation in the '60's, are now familiar to those who study drift phenomena. In regions where the ice margin became lobate upon the retirement of the ice, striae made at a stage when the locality was a score or two of miles back from the margin were liable later to be crossed

[1] Hitchcock, Edward, Op. cit., p. 85.

by a new set made when the curved border of the glacier had drawn nearer and the spreading effect of the lobe had become strongly felt. In other cases, the ice of two neighboring lobes, pushing forward unequally over a locality in successive stages left two sets of striae of divergent courses. Where a high, narrow range like the Green Mountains lay approximately parallel to ice movement, there may well have been a tendency, as the melting ice sheet thinned and lay bare the summit, but still clung to either side, for oblique upward movement, which locally and temporarily might override the summit and leave criss-cross striae. Thus two systems, one from the northwest and one from the northeast might be recorded on opposite sides or even on the same side of the Green Mountain range, as Hitchcock has described in the passage quoted. Add to this possible condition the tendency for deep, well defined valleys to deflect the course of the bottom of the moving ice mass so that it might conform somewhat more closely to those lines, and it is apparent that as evidence of local glaciers the striae of Hancock and Ripton are of little value.

Below the localities mentioned, in Hancock, on the White River, Hitchcock reported finding three "moraines," like those of the Alps. "They may in some instances have been more modified by the subsequent action of water upon their surfaces than those of the Alps; but their internal character seems to us to be the same."[1] These deposits, if we may judge from the description alone, appear to be, like those of the Black and Quechee valleys, kames, left by the departing ice sheet.

GLACIAL SCULPTURE ON SUMMITS OF THE GREEN MOUNTAINS.

Hitherto, students of local glaciation in Vermont have neglected to look for evidence of local glaciers on the higher summits of the Green Mountain range, where such glaciers must have had their source, had they existed. Although not fully appreciated by Louis Agassiz and his contemporaries, it is now well recognized that among the records left by local glaciers none are more conspicuous and characteristic than sculpture forms, such as *cirques* (bowl-like glens with semicircular head walls), *horns,* (mountain summits sharpened by the cutting back of cirque headwalls on three or more sides), *arêtes* or *comb ridges* (primary or secondary spurs narrowed and sharpened in similar fashion by cliff sapping on opposite sides). These ear marks of local glaciers are familiar features on the Geological Survey's contour maps of the Rocky Mountain ranges and Sierras. They could scarcely fail to show on similar maps of the Green Mountains if local glaciers ever have existed there. Within the past four years has come

[1] Hitchcock, Edward, Op. cit., pp. 84-85.

the recognition of these features on the Mount Washington range of the White Mountains of New Hampshire, where they apparently constitute the only evidence that remains of former local glaciers.[1] A dozen or more cirques, heading boldly around peaks which exceed 5,000 feet altitude, pass down into well developed troughs, one-half to two miles long. The limited length of these cirques and their absence from other ranges of the White Mountains where the summit levels approach or even slightly exceed 5,000 feet, would lead one to regard the Green Mountains, whose summits only rarely and slightly exceed 4,000 feet altitude, as an unpromising field for local glaciers. They are so distinct where they do occur, on the Mt. Washington range, that their presence or absence in the Green Mountains would seem to be easily settled by observation. With this in mind, I visited the two highest summits of the northern portion of the range in June, 1916,— Mount Mansfield (4,389 feet) and Camel's Hump (4,088 feet), and studied their form, to detect, if possible, any signs they might show of former alpine glaciers. Unfortunately, the U. S. Geological Survey has not yet worked in this part of Vermont, so no contour maps are available. The Rutland Sheet, however, forms a basis for judgment as to the presence or absence of glacial cirques on the sides of Killington Peak (4,241 feet), Pico Peak (3,967 feet), and Shrewsbury Mountain (3,737 feet). Nowhere, either in the field or on the maps, have I been able to find cirques or other distinct products of glacial sculpture.

MOUNT MANSFIELD.

Mount Mansfield is a long, uneven ridge, rising but 700 or 800 feet above the general skyline of the Green Mountains, in Stowe and Underhill. The trend of the mountain is nearly north and south, like that of the range; but at its northern end, there is an abrupt bend or offset of the line, where Sterling Mountain stands, farther to the east, with Smuggler's Notch, a deep north-south pass with precipitous sides, separating the two. Three or four pronounced knolls on the Mansfield crestline give it a distinct resemblance to the profile of a human face, as seen from Stowe, with the rounded forehead at the south and an equally broad, rounded chin at the north. Although the central summit or "nose" is the sharpest, forming a more conspicuous peak, at 4,094 feet, the highest altitude is on the "chin," and is 4,389 feet. As one walks along the crest, which lies at or above 4,000 feet for a distance of two or three miles, he is surprised to find how steep are the sides of the mountain, and how narrow its crest. It is also very noticeable that the spurs on the eastern

[1] Goldthwait, J. W., Glacial cirques near Mount Washington, American Journal of Science, vol. xxxv, pp. 1-19, 1913.

PLATE XXV.

A. ERRATIC BLOCKS ON MOUNT MANSFIELD.

B. SUMMIT OF MOUNT MANSFIELD.

and western sides are few and short. One, only, descends for any considerable distance out from the mountain, reaching eastward from the "nose" toward Stowe. On this spur lies the stage road to the Summit House. Two shorter spurs project from the "chin" toward Underhill, on the West side. That this is a poor field for the nourishment of valley glaciers is obvious: the area above 4,000 feet is altogether too narrow to catch snow in any considerable quantity, and the absence of long spurs and deep reentrants on the sides of the mountain leaves no pockets where drifting snows would be caught and concentrated into valley glaciers. In other words there are no linear valleys heading high up on the sides of the mountain, as in the Alps, but the mountain sides descend into broad irregular hollows or open embayments of the surrounding lowland.

Although there is a complete absence of signs of local glaciers on Mansfield, the records of the passage of the continental ice sheet across it are clear and abundant, as Professor Hitchcock recognized.[1] The ledges on the crest, except where broken out along angular joint cracks, are broadly rounded by glacial scour. Grooves and scratches, although poorly preserved on the exposures of mica schist of which the mountain is composed, show distinctly wherever the rock has been newly stripped of its mantle of boulder clay. The glaciation is from northwest to southeast. Quartz veins offer the most delicate and reliable striae, though they are visible only after the polished and striated surface has been rubbed with a lead pencil or a dirty piece of moss. On the summit are not only large angular blocks of the native stone, in positions peculiar to ice transported boulders, (Plate XXVb), but small stones of foreign origin, including red sandstone from the Cambrian belt which runs along the west base of the Green Mountains. The most interesting erratic boulder on the mountain is one of coarse syenite, in the woods, two rods from the road, on the inside of a sharp bend, 3,250 feet altitude. This boulder is an elliptical one about 5 feet long, and rests on a ledge of gray schist. Its sides have been somewhat scarred by two generations of specimen collectors, and are so round as to afford little chance for detaching more pieces. The rock is composed mainly of lath-shaped crystals of gray labradorite feldspar, over half an inch in length, with a subordinate amount of black mica, in flakes. It resembles the "anorthosite" which covers a wide area northwest of Montreal. As no nearer source of labradorite rock is known, and as the course of the ice sheet was from northwest to southeast, it is probable that the boulder traveled the 120 miles distance from the Canadian anarthosite area to Mount Mansfield. The ground moraine with which the

[1] Hitchcock, C. H., Glaciation of the Green Mountain Range, Vt. Geol. Surv., Rpt. State Geol. IV, pp. 67-85, 1904.

ice sheet mantled the Vermont hills generally, ascends Mount Mansfield, but is thin and discontinuous, on its summit, and abnormally full of angular rubbish from neighboring ledges.

There is no doubt that the passage of the ice sheet over the mountain has contributed to the steepness of the cliffs, especially on the eastern or leeward side. Below the "nose," for instance, a nearly perpendicular wall, a few hundred feet high, has developed along joint planes, as if by the quarrying action of the ice sheet. But nowhere are there curved walls such as local glaciers eat out at their heads.

CAMEL'S HUMP.

Although Camel's Hump looks very different from Mansfield because its crestline rises sharply to a single peak or knob, it consists, like Mansfield, of a long, narrow ridge, running north and south with steep sides and only a few short spurs. Only the peak itself attains 4,000 feet, and even the area above 3,500 feet is very small, having the form of a narrow strip. There are no ravines or alcoves around the summit where local glaciers might have lain. Cliffs are boldly developed on the south and east sides of the Hump, but not as curved headwalls of ravines, for there are no big ravines there. On the mountain are scoured ledges, striae, perched boulders, and erratics left by the ice sheet. As on Mansfield evidences of the former existence of the continental glacier on the mountain are numerous; but evidence of former local glaciers is nowhere to be found.

KILLINGTON, PICO AND SHREWSBURY PEAKS.

The forms of the peaks east of Rutland, as already stated, are shown in detail on the Rutland Sheet. Although this map was made in 1888-91 when the topographers of the Geological Survey were much less skillful in portraying topographic character, well formed cirques, were they present, would surely not be lost sight of, for the quadrangles of the Mount Washington range of about the same date, show cirques, though somewhat crudely.

The contours on the sides of Killington, Pico and Shrewsbury Peaks show no accentuated slopes or walls at the valley heads. The valleys originate faintly in sloping hollows which have narrow beds and descend steeply to wide, irregular drainage basins or lowlands enclosed among the mountains. A few of these mountain-side hollows exhibit contours of semicircular design,—notably one on the northeast side of Killington Peak; but they are so spaced as to preclude the possibility of the existence, in them, of a high head wall. It seems safe to conclude, therefore, that no such glacier-carved cirques exist here as show so plainly on the maps of Mt. Washington.

SUMMARY.

The evidence of the former existence of local glaciers in Vermont, which Edward Hitchcock and his associates seemed to find, in the survey of 1854-61, and which Professor C. H. Hitchcock supplemented, in his report of 1909, is of questionable value.

Some of the striae attributed by these observers to the local glaciers have the same course as striae which the same observers rightly attributed to the continental ice sheet; other striae which occur in two or more sets, can likewise be explained here as elsewhere by changes in the course of currents in the ice sheet. Moreover, attention is now called to cases, in valleys where local glaciation was suspected of striae which run (a) *transverse* to the valley, and (b) *up,* instead of down the valley,—both cases being parallel, however, to the course of the continental ice sheet, as determined by hilltop striae and the dispersion of drift. Alleged evidence of local glaciation in the form of scrubbed hillsides and ledges, similarly, is rejected as the work of the ice sheet rather than of valley glaciers.

The "terminal moraines" which first led Edward Hitchcock to adopt the view of former local glaciers—notably the "moraine" of the "Black River glacier"—are kames, similar to those of other parts of New England, both in structure and form, and associated, as usual, with kame terraces, eskers, and outwash plains.

The "glacier" valleys lack those features that distinguish valleys in which glaciers have worked; in most cases they are gorge-like and crooked; in one case (the Sherburne-Black River valley), the steep-sided, trough-like form is known to be due to its conformity to a straight belt of limestone along the flank of the Green Mountain anticlinal fold. These valleys head in situations where the opportunity for the collection of snow in excessive quantity is inferior to that elsewhere in the Green Mountains. At the head of the "Quechee glacier," in Plymouth, kames and spillways are so related as to prove that when the ice sheet melted away it left not a glacier but a temporary lake.

Finally, the entire absence of cirque forms near Mt. Mansfield, Camel's Hump, Killington Peak and other high summits of the Green Mountains, where, if anywhere, signs of local glaciers should remain (as they actually do on the Mt. Washington range of New Hampshire), makes it very unlikely that local glaciers ever existed in Vermont.

This conclusion is in harmony with that recently reached regarding the local glaciers of the White Mountains,—namely, that those glaciers were limited to the highest part of the central and highest range of that group.

The climate at the close of the glacial period, in Vermont, appears to have been so mild that the retiring ice sheet left the Green Mountains free from snowfields and alpine glaciers.

REPORT

OF THE

STATE GEOLOGIST

ON THE

MINERAL INDUSTRIES AND GEOLOGY

OF

VERMONT

1915-1916

TENTH OF THIS SERIES

GEORGE H. PERKINS

State Geologist and Professor of Geology
University of Vermont

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TABLE OF CONTENTS.

LIST OF PLATES.

FIGURES IN THE TEXT.

THE PHYSIOGRAPHY OF GREENSBORO, HARDWICK AND WOODBURY, VERMONT.

Submitted as a part of the requirement for the Degree of Master of Science, at Syracuse University.

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CONTENTS.

INTRODUCTION.

During the summers of 1913-14, it was my privilege to be a member of a Geological Survey party under the direction of Prof. Charles H. Richardson of Syracuse University, into the townships of Greensboro, Hardwick and Woodbury, Vermont. For the past twenty-one summers, Dr. Richardson has been working in the interests of the Vermont Geological Survey; and in the later years one of the phases of his work has been in tracing the erosional unconformity between the Cambrian and Ordovician terranes from the international boundary on the north, southward

through the towns of Newport, Coventry, Albany, Craftsbury, Greensboro, Hardwick, Woodbury, Calais, East Montpelier, and the city of Montpelier, a distance of approximately 75 miles. Obviously, the territory selected for the work of these two seasons was such that it would be possible to carry the work along the line of this unconformity, southward from the point where the field work of Richardson was finished the preceding season.

The object of the party was to study in detail the topographic, stratigraphic, paleontologic, and economic features of the townships of Greensboro, Hardwick and Woodbury. Various members of the party were given different problems to solve. The writer of this thesis was assigned the problem of the surficial geology of the area involved. The problem, in addition to possessing all the difficulties encountered in a glaciated region like central New York, is made still more difficult by the complexity due to intense folding, faulting, and shearing; also to the great number of acidic and basic instrusives that make their appearances in the form of dikes, stocks, sills and huge batholiths.

The work was accomplished each year from centrally located camps. During the summer of 1913, a greater part of the time was spent in the townships of Greensboro and Hardwick with the camp located on the southwest shore of Caspian Lake; and in 1914, in the townships of Hardwick and Woodbury with the camp on McCrillis Point on the eastern shore of Greenwood Lake in Woodbury.

From these two points as bases, the geology of the three townships was examined in detail. The dip and strike of each outcrop was noted. The maps showing the rock distribution of this area appear in the ninth biennial report of the State Geologist of Vermont, Plates XLVIII, LXIV, and LIII. From these maps it is possible to indicate just what rocks are most favorable to stream erosion, weathering, etc. The cross-sections accompanying each map indicate how the drainage is guided by the underlying rock structure.

WORK ALREADY DONE.

In the year 1858, the people of Vermont realized the necessity of knowing something of the natural resources of the state. The State Legislature secured the services of Edward Hitchcock, then president of Amherst College; and he, with his two sons, Edward Hitchcock, Jr. and C. H. Hitchcock, and A. D. Hager, made a survey of the geological resources of the state. Their report was published in 1861, and met the needs of the people for some time. The report, however, was largely a work of reconnaissance; and detailed study in later years, through various parts of the state, has shown it to contain so many errors as to be of little value other than as a source of general information.

Considerable reconnaissance work has been done in northern Vermont, but the only detailed work near or within the area in question has been done by C. H. Richardson in Newport, Troy, Coventry and Craftsbury; and by C. H. Richardson, E. F. Conway and M. C. Collister in Irasburg and Albany. In addition to this work, C. H. Richardson, H. G. Turner, A. E. Brainerd, and the writer have made a detailed study of the terranes of Greensboro, Hardwick, and Woodbury.

WORK UNDERTAKEN.

It is the aim of the writer to set forth the topographical features of the townships of Greensboro, Hardwick and Woodbury. In order to carry out this work it is necessary to determine as far as possible the effects produced by diastrophic movements, glaciation, weathering, and stream action. In the absence of a topographic map of the area, the various topographic features and points of interest are located as nearly as possible on an outline map.

METHOD OF ATTACK.

The problem as indicated includes only the surficial features, and as far as stratigraphy and changes brought about by economic projects are concerned, they will be dwelt upon only in instances where they affect the topography of the area traversed. In order to arrive at the solution of the problem, a comparison must be made with adjoining, and even remote, areas for more general correlations. This, however, forms only a small part of the problem; in fact, it merely serves as a method of transition from type localities to the area here involved. Topography, drainage and glaciation form the main topics for discussion.

It is probable that no other section of Vermont affords more interesting problems or more unique features of drainage than the systems found in these three towns. The glaciation of the area must also be traced in great detail. This feature has played a very important part in the topographical history of the area and one that will always present problems for solution. In addition to the drainage and glaciation, a few smaller causes for topographical changes may be cited; namely, weathering agencies outside of water as a means of drainage and artificial construction. The latter, though of limited extent, has produced marked local changes in the land features. Hence the solution of the problem lies in correlations with contiguous and remote areas, drainage, glaciation, weathering agencies and artificial construction.

In carrying out the actual field work, each highway, railroad, elevation and valley was carefully examined. The altitudes of all terraces were recorded for comparison and interpretation as to origin. The various characteristics, extent, dip, and strike of the underlying terranes were determined; and the upper surfaces of the rocks, especially the more resistant varieties, were carefully noted, to discover any evidences of glacial striations. The mantle rock was studied to determine whether the material was residual or transported, and if transported, whether in the form of alluvial terraces that mark old water-levels, or glacial drift. The drift was also examined to ascertain, if possible, the location of any kames, eskers, drumlins, moraines, etc.

GEOGRAPHY.

The area traversed lies, geographically, between the parallels 44 degrees and 23 minutes and 44 degrees and 40 minutes north latitude; and longitude 72 degrees and 15 minutes and 72 degrees and 30 minutes west of Greenwich. It comprises an area of approximately 120 square miles. Greensboro is located in the southeastern part of Orleans County; Hardwick in the western part of Caledonia County; and Woodbury in the northern part of Washington County. The east and west boundary lines of the townships extend in a direction north 40 degrees east, which corresponds practically to the general strike of the sedimentaries of that region; while the north and south boundary lines extend along the parallels of latitude given above.

TOPOGRAPHY.

The physiographic location of the area is in the New England Ridges, which may be regarded as a subdivision of the Appalachian district. The uplift of this area occurred at the close of the Ordovician period, at which time a withdrawal of the sea converted large portions of North America into land masses.

The areal maps of the three townships reveal the fact that the more important valleys are longitudinal, except the Lamoille in western Hardwick and Wolcott; while most of the minor valleys are transverse. The well-defined longitudinal valleys or the valleys that are roughly parallel to the meridians of longitude are a result of streams wearing along the strike and cleavage planes of the rocks, and the continental glacier has also scraped out and deepened the pre-glacial valleys resulting sometimes in a broad U-shaped valley. In some instances these valleys are narrow and constricted, as for example, the valley known as Woodbury Gulf south of Hardwick village, which has very steep sides with a somewhat flat bottom.

The most important valley of the region is that of the Lamoille river, which drains a greater part of the three townships. The river begins in the northeastern part of Greensboro and Stannard, by the union of several small streams, one of which was the former outlet of what is now known as Runaway pond of Glover, and extends in a southerly direction along the strike of the rocks. It keeps in such a course until it reaches a point about one-half mile north of East Hardwick, where it begins to deviate from this course. Below East Hardwick, the valley turns suddenly to the westward, cutting across the strike of the rocks of this area; thence across the Green Mountain axis to Lake Champlain. The main valley of the Lamoille in this area is a broad U-shaped pre-glacial valley noted for its fertility and scenic beauty.

Perhaps the most noticeable feature of the Lamoille valley is the terraces along its extent. These ancient water levels are especially well shown near the outskirts of the village of Hardwick where they occur at levels ranging from 810 to 1,050 feet above sea level. On the banks of Woodbury Creek near the Lamoille river, there is a level of sand through which the stream has cut, giving it a terrace form at the elevation of 810 feet above sea level. The next level is near the oil tanks west of the granite sheds of the Woodbury Granite Co., at an elevation of 825 feet. In the same locality, the next bench occurs at an elevation of 880 feet. Passing on up the steep slope of Buffalo Mountain, there are two other levels, one at 940 feet, the other at 1,050 feet.[1] These old waterlevels are very clearly preserved in this locality, and from the successive terraces it is possible to look across the broad valley of the Lamoille and see these benches preserved in broad stretches on the opposite side. The most noticeable of these is the terrace upon which the Hardwick Hospital is built. The St. Johnsbury and Lake Champlain Railroad at the station of Hardwick is also located on the next lower terrace from that on which the hospital is situated. On the east side of the village near the cemetery and along the Woodbury Gulf, these sand terraces occur in dissected masses, resembling, as far as outward appearance goes, the structure of kames or kame terraces. A close observation reveals the fact that they are perfectly stratified and contain no coarse gravels except what is included by a thin band of glacial till which caps the mass. (Plate XXVI).

Farther west on the Lamoille about half a mile below the dam of Hardwick Lake, four distinct terraces are found which correspond to those found on Buffalo Mountain. The highest of these is 880 feet, and the lowest at approximately 800 feet. The latter is the lowest level found in this area.[2] The river at this point is at an elevation of 775 feet above sea level which is likewise the lowest point encountered, as it marks the point where the master stream leaves the area. The valley in this part of the township is broad and U-shaped. The river meanders considerably on its flood plain, and is the most fertile as well as beautiful section of the township.

[1]Richardson, C. H., Brainerd, A. E., and Jones, D. J.; The Geology and Mineralogy of Hardwick and Woodbury, Vermont; 9th Report of the Vermont State Geologist, 1913-1914, p. 302.
[2]Idem, p. 302.

PLATE XXVI.

TERRACE A HALF MILE WEST OF LAMOILLE RIVER, EAST HARDWICK, ALTITUDE 1,250 FEET.

PLATE XXVII.

OUTCROP OF PHYLLITE SCHIST DIP EAST, A. S. CLAY FARM, GREENSBORO.

In the eastern part of Greensboro, near Greensboro Mills, Greensboro Bend, and at various places along the river in that vicinity, there are terraces which are delta-like in form, being developed best at the base of the small transverse valleys. At Greensboro Bend there are three sets of these benches from approximately 1,140 to 1,160 feet above sea level. A short distance below Greensboro Mills, these alluvial terraces are strikingly well preserved in flat benches. A few feet above the river bed, and directly back of them is a large amount of drift, cut in many places by small incisional valleys at right angles to the main stream, and showing clearly the origin of the material found in the terraces. The elevation corresponds very nearly to the 1,160 foot level found at Greensboro Bend.

Along the Woodbury Gulf a short distance above Hardwick on the road to South Woodbury, there is a deposit of sand worked for commercial purposes, which is known as Martel's sandpits. The elevation at the base is at the 850 foot level, while the top is 925 feet above sea level. Farther south, along the railroad of the Woodbury Granite Company, half way between Woodbury and Hardwick, there is a terrace of the same material at the elevation of 1,080 feet.

The Eligo Valley in most places is broad, U-shaped, and longitudinal and is unquestionably pre-glacial. The valley extends from its union with the Lamoille a short distance west of the village of Hardwick in a direction north 40 degrees east through the western part of Hardwick and the southwest part of Greensboro, into the southeast corner of Craftsbury. At this point a very low valley divide or col separates it from the Black River valley which extends in a northerly direction to Lake Memphremagog. "Its course was determined in pre-glacial times by the sharp folding of the Ordovician limestone and slate against the Cambrian schists to the west."[1] The character of the valley indicates that it has moved along the cleavage planes of the westwardly-dipping limestones and slates until at present it lies practically at the contact of these rocks and the Cambrian schists on the west. This is an excellent example of a stream valley being determined by the degree of solubility and fissility of underlying rocks. The rocks to the west are insoluble, and moreover, the stream was not wearing along the planes of schistosity, as in the case of the limestones and slates which had a very high westerly dip. (Plate XXVII).

The tributaries to Eligo Valley are mainly small transverse post-glacial ravines or valleys, the most important of which is the valley of the Cascade brook, which enters the Eligo Valley from West Hill about half a mile above Hardwick Lake. On the west

[1] Richardson, C. H., Brainerd, A. E., and Jones, D. J.: The Geology and Mineralogy of Hardwick and Woodbury, Vermont; 9th Report of the State Geologist of Vermont, 1913-1914, p. 298.

side of the valley, the transverse ravines are located in the resistant Cambrian quartzites and schists, which have a high dip to the east, and as a result the brooks have a high gradient and in many cases find their way to the main valley by means of a series of cascades. On the east side, small ravines are developed across the strike of the westerly-dipping sedimentaries at right angles to the strike and the volume of the streams located in them is not sufficient to change the topography to any extent.

South from Hardwick Village as far as West Long Pond or Greenwood Lake, there is a very typical pre-glacial, longitudinal valley known as Woodbury Gulf.[1] At or near Greenwood Lake the valley divides because of the appearance of a belt of resistant rock. One branch extends down through Woodbury thence to the Calais line, while the other extends in a general southwest direction roughly corresponding to the line of contact between the Ordovician limestones on the east and the Cambrian terranes on the west, crossing the Calais line about one mile east of the western boundary of Woodbury. The valley is narrow, steepsided, U-shaped and is an excellent example of a pre-glacial U-shaped valley that has been scooped out and deepened by the advancing ice sheet. At the lower end of Greenwood Lake there is a deposit of glacial gravels attaining a thickness of 150 feet, forming the obstruction which gives rise to that body of water. This valley filling is a mixture of a small amount of clay and a predominance of fine and coarse gravels having little if any evidence of lamination. It may represent a part of the terminal moraine left by the glacier. The west side of the valley is for the most part a steep cliff made up of a long ridge extending from Buffalo Mountain on southward through Woodbury Mountain to the Calais line. This ridge is composed of granite intrusions, resistant quartzites, schists and slates which are insoluble and not easily eroded, giving rise to a series of beautiful waterfalls wherever a tributary stream enters the valley. The east side along the railway of the Woodbury Granite Company is not quite as steep, it being composed of the less resistant sedimentaries. Here again is a case of a stream eroding along the strike of the rocks, working its way westward to the line of contact between the Ordovician limestones and the Cambrian terranes.

DRAINAGE.

It is doubtful if any other portion of the State presents more interesting problems of drainage than those to be considered in this thesis. In order to understand the question more fully, it will be necessary to consider briefly the pre-glacial as well as the post-glacial drainage of the area.

[1] Richardson, C. H., Brainerd, A. E., and D. J. Jones: The Geology and Mineralogy of Hardwick and Woodbury, Vermont; 9th Report of the Vermont State Geologist, 1913-1914, pp. 298-299.

POST-GLACIAL DRAINAGE.

The Lamoille is the master stream of the area and drains a greater part of the three townships, with the exception of the southeastern part of Woodbury, which is drained by the Winooski system; and the northwestern part of Hardwick and western Greensboro, which finds it drainage through the Black River and thence to Lake Memphremagog. The Lamoille, with its headwaters in the eastern part of Greensboro and western Stannard, flows in a southerly direction through eastern Greensboro and Hardwick until a short distance below East Hardwick. Here it turns in a westerly direction, through the village of Hardwick, across the Green Mountain axis, and finally empties into Lake Champlain.

In the township of Greensboro, the streams flowing into the Lamoille are small and might be regarded as its headwaters. The principal ones are the outlets of Long Pond, Mud Pond and the former outlet of a pond in Glover, now widely known as the "Runaway Pond of Glover," whose outlet since the year 1810 has been to the north.

A brief history of this pond might be of interest at this point, although it is not located within the area in question. The effects produced by it, however, are somewhat noticeable in Greensboro.[1] In the year 1810 a pond having a depth of 60 to 100 feet, a width of one-half to three-fourths of a mile, and a length of about two miles, located in Glover near the northern boundary of Greensboro, just north of Horse Pond, had its outlet to the south through Horse Pond and formed part of the headwaters of the Lamoille. It was observed that a very small channel would reverse the drainage and give abundant waterpower to the mills along Barton River to the north. Accordingly a channel was started and great was their surprise when the water began to flow to the north through a bed of quicksand and rapidly to drain the basin. Messengers were sent to warn the inhabitants of the valley and by virtue of a wooded territory which served as a dam to hold the flow in check, they escaped without loss of life.

At the present time, a deep pit with a swampy bottom composed of clay and marl and its sides dotted here and there with deposits of lake sand, testifies to the former existence of that body of water. Within a few feet of the Greensboro line a small, dry, V-shaped channel extends down to Horse Pond. This shows the valley through which the waters of Long Pond, as it was then called, reached the Lamoille.

South of the headwaters of the Lamoille for some distance the tributaries are small, post-glacial streams that flow at right angles to the main stream valley. These streams have cut small

[1] Geology of Vermont, 1861, pp. 729-730.

V-shaped notches through the glacial drift and in some cases are eroding the underlying terranes. Their effects, however, are limited mainly because of the lack of volume and of the fact that they are flowing at right angles to the strike of the underlying limestones and phyllites, and thus are unable to adjust themselves to the softer layers.

Mill Brook enters the Lamoille near the Nelson farm about one mile above East Hardwick. This stream has its headwaters in Caspian Lake and drains the central portion of Greensboro east of Mt. Sarah, south of Barr Hill, and west of East Hill. This brook flows in a southerly direction and the valley is undoubtedly pre-glacial although its course is considerably modified by the effects of glaciation as the stream is flowing almost entirely in glacial drift and alluvial material brought down by its own action.

Between this brook and Hardwick Village, there are only three tributaries worthy of mention. The first is the outlet of Tottie Pond which enters the Lamoille a short distance above East Hardwick. The next one flows in a westerly direction parallel to the road leading to Walden, about one and three-fourth miles above Hardwick Village. This stream has cut down to the underlying limestone and with its steep gradient forms many beautiful cascades. The third stream mentioned above, rises near the southern boundary of Greensboro and flows nearly due south, draining a considerable portion of the central and northern part of Hardwick, entering the Lamoille one mile above the village of Hardwick. At a distance of approximately a mile from its confluence with the Lamoille, it begins to cut across the strike of the underlying sedimentaries, and has a drop of 150 to 200 feet, which results in a series of picturesque cascades and waterfalls.

At the village of Hardwick the Lamoille receives two tributaries, namely, Nichols Pond brook and Alder Creek. Nichols Pond brook has its headwaters in East Long Pond and Nichols Pond in the northeastern part of Woodbury. It receives a tributary in southeastern Hardwick which rises near the Walden line. The stream flows in a northwesterly direction and empties into the Lamoille near the sheds of the Woodbury Granite Company. Cooper's Brook rises north of the summit of Woodbury mountain, flows east over the steep side of Woodbury Gulf just north of Greenwood Lake, and thence along the gulf where it flows into Nichols Pond brook near the southern limits of the village of Hardwick. On the west, this brook drains the east side of the ridge from Woodbury Mountain to Buffalo Mountain; and on the east, the area north of the Buck Lake district.

The headwaters of Alder Creek, for a greater part of the year, at least, are in Little Eligo Pond, from which it flows in a southerly direction along the line of contact of the Cambrian and Ordovician terranes and empties into Hardwick Lake. On the east, Alder Creek receives a few very small tributaries which drain the area west and south of the poor house. The tributaries from the west are small and unimportant, with the exception of Cascade Brook, which enters Alder Creek about one-half mile above Hardwick Lake.

Cascade Brook is the outlet of three small ponds or reaches. The valley of this brook is a hanging valley with three successive levels. Granitic intrusions are in part responsible for the falls at Tuckerville. At the junction of the valley with that of Alder Creek, there are a series of cascades over which the water falls for a distance of 125 feet to the Alder Creek valley.[1]

In the western extension of the Lamoille, there are three small tributaries, two from the north draining the southern and western part of West Hill and one from the south rising on the west side of Woodbury Mountain.

The Memphremagog or northern basin includes the region in northwestern Hardwick and western Greensboro which lies approximately within a line drawn from the crest of Smith Hill to the crest of Mt. Sarah, then south to the Hardwick line. The master stream of this basin is the Black River, which is the outlet of Big Eligo Pond and lies entirely outside this area. It flows in a northerly direction to Lake Memphremagog. The streams in this basin are small post-glacial streams which flow in a westerly direction, into the Black River in the township of Craftsbury.

The Winooski or the southern basin drains the southeastern part of the township of Woodbury. The divide between this basin and that of the Lamoille runs in a zigzag line from the eastern border of the township of Woodbury in a westerly direction just south of Pickett's Pond, skirting the south end of Robeson Mountain, where it takes a northerly course around Buck Lake. From this point it extends in a southwest direction cutting Woodbury Mountain on a line just north of Greenwood Lake. Along the east side of the township, the streams flow in an easterly direction into the township of Cabot. The outlets of the small Mud Pond in southeastern Woodbury, Buck Lake, Greenwood Lake, Valley Lake and all other small streams included in this circle, drain into Woodbury Lake and thence to the Winooski River. Nelson Pond receives the water from a few small streams east of the Slayton Pond district, and west of South Woodbury. The outlet of Slayton Pond is to the west into Elmore, thence into the Lamoille.

[1]Richardson, C. H., Brainerd, A. E., and Jones, D. J.: The Geology and Mineralogy of Hardwick and Woodbury, Vermont, Ninth Report of the Vermont State Geologist, 1913-1914, p. 299.

PRE-GLACIAL DRAINAGE.

The great amount of glacial debris prevents any detailed account of the pre-glacial drainage. The main valleys of the area are the Lamoille, the Eligo and the Woodbury Gulf. These valleys are clearly pre-glacial and have resulted from the gouging out of V-shaped valleys until they have become typical U-shaped valleys. Thus, the only conclusion possible is that pre-gacial drainage was through these depressions which were largely determined by the folding of the underlying terranes. Are the divides of the present day located at the same places as in preglacial times? In all probability, the height of land separating these drainage basins has not changed to any great extent. The Woodbury Gulf conforms to the strike and cleavage of the underlying terranes until it gets to a point near South Woodbury with a high altitude where the strike changes abruptly from north 40 degrees east, to nearly east and west. A north or south flowing stream under the above conditions would be flowing across the strike of the rocks. Hence, it seems only reasonable, with lower land north and south, that this condition would produce a divide permanent for all times; inasmuch as streams with small volume do comparatively little eroding while flowing at right angles to the planes of cleavage because they are unable to adjust themselves to the softer layers.

The height of land in the northern part of the Lamoille basin is due partially to granitic intrusions which have forced the rocks upward and also to the intense folding to which that area has been subjected; so in all probability this divide has not been changed to any extent by glaciation.

In the case of Eligo Valley, where stream action has taken place along the strike of the rocks, there is a strong possibility for the shifting of the divide so that in pre-glacial times all of the drainage might have taken place to the south through the Lamoille basin; or a part might have gone north into the Memphremagog basin, as it does at the present day.

The other valleys of the area are smaller and are subordinate to those described. Most of them are transverse post-glacial valleys and their courses are subject to minor changes, such as solution, differential erosion, valley filling, etc.

The only conclusion that can be drawn is that the drainage in pre-glacial times was very similar to that of the present, as far as the major streams are concerned. Further interpretation of the drainage is made difficult by the presence of a large amount of morainal material and no attempt was made to work out the tributary drainage.

REVERSED DRAINAGE.

The former drainage of the now extinct pond in Glover known as the "Runaway Pond of Glover" was south through

Horse Pond into the Lamoille River, but by cutting an artificial channel at the north end, the drainage was shifted in that direction. This outlet cut into a bed of quicksand, which rapidly drained the pond, leaving the practically dry channel from the north Greensboro line to Horse Pond devoid of its parent water supply.

One mile north on Mount Sarah, on the road leading back to Greensboro village, there is a short, steepsided, longitudinal valley which forms a connection between two parallel, east and west tributaries of the Black River. This is a glacial valley, cut partly by glacial ice and partly by the erosive action of the water. At the time when the valley of East Craftsbury Brook was obstructed there was a southern drainage of that brook through this channel.

The feature of greatest interest in the whole area is found at Big Eligo Pond in the southwestern part of Greensboro. This pond is situated very near, if not quite on, the height of land separating the Lamoille and the Memphremagog basins. At one time, and that not far past, this body of water had two outlets one to the north through the Black River into Lake Memphremagog, the other south through Little Eligo Pond, which is located about one-half mile to the south and which has its outlet through Alder Creek into Hardwick Lake.

The finding of water levels in this vicinity corresponding to the Memphremagog levels, shows that in glacial times there was a drainage to the south over this divide from Glacial Lake Memphremagog into the Lamoille basin or Glacial Lake Champlain.[1] There is very little difference in the altitudes of these two ponds and the area between them is flat and swampy. The streams in this portion are very sluggish, and it was with difficulty that a portion of this water was seen to have a northward movement and the remainder a southward movement. This places the true divide midway between the two ponds. The readings of the aneroid show that with a rise of two or three feet in the water-level of Big Eligo, there would be a distinct drainage to the south from this body of water.

In the ninth report of the State Geologist of Vermont, page 279, on the "Terranes of Greensboro, Vermont," by C. H. Richardson, and H. G. Turner, the following statement is made. "Eligo Creek and Whetstone Brook in Craftsbury were the head-waters in pre-glacial items for Eligo Pond and subsequently for the Lamoille River. If this conjecture be true, we have here an excellent illustration of the migration of a divide and the beheading of a stream. This accident would explain the abrupt turn to the north of streams whose initial waters flow in a southerly direction in Craftsbury. How much of this work may have

[1] Hitchcock, C. H.: The Champlain Deposits of Northern Vermont. Fifth Report of the Vermont State Geologist, 1905-6, p. 248.

been accomplished by the ice when it moved to the south, broadening and deepening the valleys, I cannot say." The geologic map opposite page 164 in the eighth report of the State Geologist of Vermont gives a great deal of weight to the above conjecture, for the tributaries mentioned as well as the branches of these streams, flow in a southerly direction till they reach the Black River, where they turn to the north and form part of the headwaters of that stream. This indicates rather strongly that these streams, once a part of the pre-glacial drainage system of the Lamoille, were subsequently reversed, and became a part of the Memphremagog system; a deduction made from the fact that under normal conditions the tributaries flow in the same general direction as that taken by the master stream, rather than in nearly diametrically opposite directions, as in the case in question.

The results of my investigations are as follows:

1. In pre-glacial times the area around Eligo Pond had its drainage to the south into the Lamoille basin.

2. As a result of continental glaciation and stream action, a divide has been established between Big and Little Eligo Ponds.

3. Under normal conditions of precipitation, this divide lies between the two ponds; but under abnormal conditions, resulting in a rise of the water level of Big Eligo to the extent of two or three feet, the divide shifts to the north, and gives the pond an outlet to the south as well as to the north.

Buck Lake in the northeastern part of Woodbury presents features indicating changes in drainage.[1] At the present time, the lake has its outlet to the south into the Winooski basin. However, as the lake is viewed from an elevation, it is seen that there is a distinct valley to the north, leading down to Woodbury Gulf, thence to the Lamoille at Hardwick. This indicates that the pre-glacial drainage of this area was to the north, but an obstruction of glacial drift caused the waters to spill over the divide into the Winooski basin.

GLACIATION.

That the townships of Greensboro, Hardwick and Woodbury were once covered by a continental glacier is proven by the existence of vast quantities of stratified and unstratified drift. This drift, however, forms but a small part of the evidence left by this invader of the land. Among such evidences, perhaps the most common are the glacial striae left on the rocks which indicate the direction taken by the glacier in its forward movement. In addition to these features there are eskers, kames, kettle moraines, sand terraces, boulders of various kinds, incised or gouged out valleys, glacial lakes and drumloid hills.

[1]Richardson, C. H., Brainerd, A. E., and Jones, D. J.: The Geology and Mineralogy of Hardwick and Woodbury, Vermont. Ninth Report of the Vermont State Geologist, 1913-14, p. 304.

PLATE XXVIII.

WOODBURY, BOULDER STREWN FIELD.

Woodbury Mountain, with an altitude of 2,800 feet above sea level, the highest peak in the area traversed, shows ample evidence of glaciation in the form of huge boulders of granite and quartzite. That the ice attained a much greater thickness, is proven by the fact that five mountains in Vermont, each having an elevation of more than 4,000 feet, are glaciated to their summits. These mountains are Jay Peak, Mansfield Chin and Nose, Camel's Hump, Killington, and Lincoln. Mount Marcy, the loftiest peak of the Adirondacks in New York State, having an elevation of 5,344 feet, bears evidence of glaciation on its summit. In addition to this, Mt. Washington in New Hampshire, with an altitude of 6,286 feet, as well as all the peaks of New England, are glaciated. Therefore, the ice sheet must have attained a thickness of more than 6,000 feet. Pressure from the north must have been very great, to have forced the ice sheet to over-ride these mountains; and it is generally conceded that the ice must have been at least 10,000 feet thick as it passed over central Vermont.

GLACIAL BOULDERS.

One of the most noticeable features of this area which can be directly attributed to the effect of glaciation, is the promiscuous distribution of countless numbers of boulders. These rocks are of various kinds, forms and sizes, and one can safely say that not a single acre of the entire area does not contain rock from some foreign locality. Where boulders become especially numerous, the area is known as "boulder-strewn," or in some localities, as a "boulder train." In many cases, the boulders occupy so much of the surface that it is impossible to till the soil, and the result is that the areas are turned over to pasture land. (Plate XXVIII).

In the area traversed, these fields were largely covered by granite boulders and they were especially abundant near large outcrops of granite; thus, in many cases, giving a clue to the source from which they were derived. These areas are found best represented south and east of Paddock Hill in the township of Greensboro. In the township of Hardwick, extensive distribution of these boulders occurs in the southeastern part along either side of the road leading past the R. C. Carter Quarry. In Woodbury, they occur in the northeastern part of the township rather as an extension of the material found in Hardwick, and also in the southeastern portion. The size, angularity, and lithologic character of the rocks in this section suggest that they were derived from the granite area on Robeson Mountain. These boulders vary in size from gravel to rock masses attaining the weight of hundreds of tons. (Plate XXVIII A). They also represent various lithologic formations including granites, diabases, camptonites, amphibolites, peridotites, serpentines, quartzites, phillites, and limestones. Some of these rocks will be discussed later in an attempt to show the direction of ice movement by ascertaining their original habitat.

Many of these boulders, where found of sufficient size, are worked for building stones, monuments, etc., under the name of "boulder quarries."[1] One of these quarries is situated about 100 rods northeast of the Mackville quarries, near the road leading from Hardwick village to the vicinity of Nichols pond. Another so-called boulder quarry is located on the W. A. Scott farm, one-half mile to the north of the Mackville quarries. This quarry is in a mass of granite about 150 feet in length and 100 feet in width. It is possible that instead of being a boulder of such large dimensions, this is in reality a part of an extensive mass of granite which is covered by glacial drift; because there is no granite area to the north from which such a gigantic boulder could be derived.

The famous "Rocking Stones of Greensboro" are situated on the Barclay farm in the northwestern part of Greensboro.[2] During the retreat of the continental glacier, these boulders, located within 25 feet of each other, were left perched on the top of two other larger boulders as a base. They are so perfectly balanced as to be easily moved with one hand. (Plate XXIX).

These two rocks are of biotite granite, perched on bases of the same material. The smaller boulder is approximately 10 x 9 x 6 feet, or, stated differently, has a volume of 540 cubic feet. The larger boulder, which is 10 x 8 x 8 feet, has a volume of approximately 640 cubic feet. This gives an estimated weight of 50 tons for the smaller and 60 tons for the larger rock.

STRATIFIED DRIFT.

Although the stratified drift is not extensive, yet it presents some rather interesting features. Scattered over the area, there are mounds of roughly stratified sand and gravel, ranging from 25 to 50 feet in height, rather circular in form and not usually more than 50 to 150 feet in diameter. They are a product of glaciation and in all probability were formed in the crevasses or cracks of the ice by means of surface streams flowing over the top of the glacier. This action deposited the materials in such a way that, in portions of the mass, stratification is evident. In many cases the material shows cross-bedding, but much of it shows practically no sorting. A good example of these gravel deposits can be found east of the road to Calais and about one mile south of Greenwood lake. These deposits are known as kames. (Plate XXX).

[1]Richardson, C. H., Brainerd, A. E., and Jones, D. J.: The Geology and Mineralogy of Hardwick and Woodbury, Vermont. Ninth report of the Vermont State Geologist, 1913-14, p. 318.

[2]Richardson, C. H. and Turner, H. G.: The Terranes of Greensboro, Vermont. Ninth Report of the Vermont State Geologist, 1913-14, p. 289.

PLATE XXVIII A.

GRANITE BOULDER.

PLATE XXIX.

PERCHED BOULDER, GREENSBORO.

In the Eligo Valley along Alder Creek, there appears a low, elongated, sinuous ridge, somewhat more than a mile in length, and from 20 to 30 feet in height. This ridge is composed of sand and gravel, and is elongated in the direction of the moving ice.[1] The ridge is a typical esker and is often spoken of as a "fossil glacial stream." The theory for its formation is as follows: Sub-glacial waters have developed a channel or elongated cavern which has been subsequently filled with sand and gravel, and upon the retreat of the glacier, the winding ridge was left to mark the former course of the sub-glacial stream.

In the area south of Robeson Mountain, the special forms taken by the drift and the effects produced by its regularity or irregularity will be taken up under separate topics. The drumloid hills of this area consist of a few low oval-shaped hills with their longer axes extending in a north and south direction, the broader ends being to the north. Their outward appearance suggests that they are typical drumlins similar to those found in central and western New York; but they are smaller in size and fewer in number. It was impossible to obtain a cross-section of any of these hills to determine their interior structure. Several of them may be found in the vicinity of the town house in the central part of Hardwick. Hills of this type occur scattered throughout the area traversed and are strikingly suggestive of drumlins.

Remnants of a terminal moraine of recession are found in Woodbury, where the rock material carried by the glacier was dropped during its retreat, while the ice sheet remained stationary for some time.[2] This line of debris stretches in an easterly direction across Vermont through Lyndon and appears again in New Hampshire.

About one mile to the northwest of South Woodbury, this debris takes the form of a kettle moraine. It is situated in a transverse valley and is composed, in this locality, of roughly stratified gravels. These have taken the form of snake-like or irregular ridges which have united so that they form cup-shaped depressions and, in some localities, are filled with water, forming what is known as kettle lakes. In this particular instance, these depressions had little or no water in them, because the material was composed of gravel, and hence had a very good drainage. The kettle holes vary from 50 to 150 feet in diameter and are from 25 to 50 feet in depth. One of the depressions, which is about 75 feet in diameter is perfectly symmetrical. The moraine is similar to the kettle district located near Tully, New York. The depressions are smaller, fewer in number, and contain little

[1]Richardson, C. H., Brainerd, A. E., and Jones, D. J.: The Geology and Mineralogy of Hardwick and Woodbury, Vermont. Ninth Report of the Vermont State Geologist, 1913-14, pp. 301-302.

[2]Richardson, C. H., Brainerd, A. E., and Jones, D. J.: The Geology and Mineralogy of Hardwick and Woodbury, Vermont. Ninth Report of the Vermont State Geologist, 1913-14, p. 301.

water; while those at Tully contain many beautiful lakes or ponds.

UNSTRATIFIED DRIFT.

The unstratified material is by far the most extensive. The greater part of the area is covered by a heavy mantle of till, varying in thickness from a few inches to many feet. A few of the elevations bear little or no evidence of this material, but seem to have been scraped over; and in many instances, these rocks present a smooth, polished surface. The localities where there is a paucity of drift are in the vicinity of Paddock Hill in the northern part of Greensboro and on the Cambrian hills west of Eligo pond in Greensboro. In the township of Hardwick, the area west of the line of contact between the Ordovician limestone and the Cambrian hills may be taken as the location where drift is very scarce.

In the township of Woodbury, the Cambrian hills along the western border and portions of the granite area in the northeastern part are the only places of any extent where glacial drift is not prevalent. Even in the areas enumerated, there will be found locally considerable morainic material, especially in the form of boulders.

The remaining portions of the three townships are covered by a thick mantle of drift so that rock outcrops are very scarce and ordinarily occur only in the ravines and road cuts. The southern part of Greensboro and northern Hardwick have a very extensive mantle of drift. In Woodbury the greatest thickness is attained in the southeastern part of the town.

ANCIENT WATER-LEVELS.

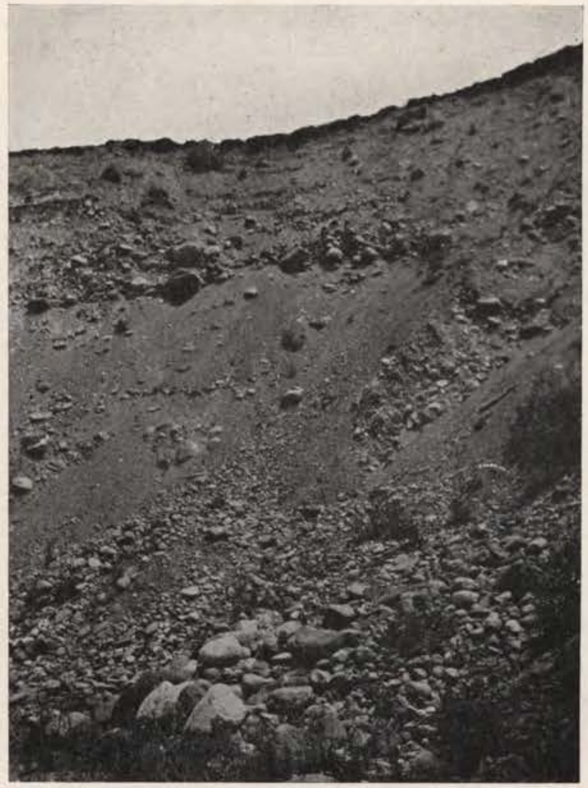
In several places over the area traversed, distinct sand and gravel terraces occur at an elevation of approximately 1,250 feet. These are undoubtedly terraces formed by Glacial Lake Vermont, possibly at its highest stage. These terraces vary in altitude, possibly because of conditions of erosion or unequal diastrophic movements.

The development of Glacial Lake Champlain or Lake Vermont, according to Prof. Perkins,[1] was as follows:

"For some cause which can only be postulated from the known conditions of the time, and hence probably the effect of the powerful discharge of the drainage through the Hudson Gorge, coming not only from the melting ice in the Champlain district, but as well from the intake from Lake Iroquois which was now in existence on the west of the Adirondacks, the waters of Lake Albany were drained off. With the withdrawal of the

[1] Perkins, G. H.: General Account of the Geology of the Green Mountain Region. Eighth Report of the Vermont State Geologist, 1911-1912, pp. 44-45.

PLATE XXX.



BED OF GRAVEL NEAR NORTH END OF ESKER, ELLIGO VALLEY, HARDWICK.

waters over the Albany district, a divide partly of glacial materials and partly of bed rock was revealed between the nascent lake over the Fort Edward basin and in Lake Champlain valley, and the region on the south, and waters began to spill over the barrier west and south of Schuylerville across those fields which were later the scene of Burgoyne's defeat. Thus Lake Vermont was born, consisting on the south of the mountainous ridges between two of which Lake George lies, of a shallow lake over the Fort Edward district, and a constantly enlarging body of water on the north."

Later in the article, Prof. Perkins states that "At the time of its greatest enlargement Glacial Lake Champlain was several hundred feet higher than now, and it has been thought by some writers that possibly there might at one time have been a flow through the Green Mountain divide into the Connecticut valley."

It seems, then, perfectly logical, in view of the foregoing statement, to assume that these high sand terraces are those left by Lake Vermont, possibly at its highest stage.

In connection with these observations, it is noted that the valley divide that separates the headwaters of the Black River, which flows into Lake Memphremagog at Newport, from the source of Alder Creek, which empties into the Lamoille River one mile west of the village of Hardwick, is approximately 850 feet.[1] There must have been a commingling of the waters of Lakes Vermont and Memphremagog at some period in the history of these bodies of water. Altitudes taken at the divide in Woodbury Gulf that separates the waters flowing north into the Lamoille and south into the Winooski, are approximately 1,000 feet, thus indicating a commingling of waters between the Lamoille and Winooski basins. The altitude of the Williamstown Gulf in Orange county is not sufficient to have precluded an outlet for Lake Vermont into the White River and Connecticut valley.

Fragments of these high terraces may be found in the following places[2]: one mile northeast of East Hardwick, on the east side of Eligo Valley near the poorhouse farm, near the west line of Hardwick on West Hill, and also just west of number 10 schoolhouse in the eastern part of Hardwick. A succession of terraces was found along the Lamoille having the following altitudes: 810, 825, 880, 940, 1,050, 1,100 and 1,140 feet. The first four form a series of steps up the slope of Buffalo Mountain southwest of the sheds of the Woodbury Granite Company. These terraces indicate in a way the successive levels of Glacial Lake Vermont.

[1]Richardson, C. H., Brainerd, A. E. and Jones, D. J.: The Geology and Mineralogy of Hardwick and Woodbury, Vermont. Ninth Report of the Vermont State Geologist, 1913-14, p. 302.

[2]Idem.

STRIATIONS.

These markings are not as abundant or conspicuous as many other glacial features of the region. The striations themselves range from minute scratches, scarcely visible to the naked eye, to grooves a quarter of an inch in diameter. In other localities these glacial markings appear as polished surfaces or as shallow grooves having a width of several inches. Thus it is evident that the abrading due to the movement of the rocks frozen in the ice must have been no small factor in the erosion accomplished by the glacier.

The rocks best adapted for the preservation of these markings are the highly tilted slates, the resistant phyllites, the quartzites and the vein quartz. They are not often preserved on the granites, due to the variety of composition and the texture of the rock, which causes it to break up easily with variations in temperature. The limestones of the region seldom show these striations, but in other localities, such as in central New York, they are frequently preserved in distinct parallel grooves.

A study of the glacial striations found in this area reveal the fact that there were three distinct directions taken by the advancing ice sheet; namely, south 20 degrees east, south 30 degrees west, and south.

Observations to determine the relative age of these movements resulted as follows. One mile north of Greensboro Village, on the road leading past the school building, the striations having a direction of south 30 degrees west, cut those having a direction south 20 degrees east. Those having a direction due south cut both the preceding sets. These results were checked by similar conditions south of Robeson Mountain, showing the relative age of the striations to be: oldest, south 20 degrees cast; next in age, south 30 degrees west; and the youngest, due south.

There is a variation in direction from the above sets to the extent of several degrees shown in the table of striations. This may be due to variations in the topography, a slight shifting in the forward movement of the ice, or a change in the position of the abrading material.

Glacial striations observed in northeastern Vermont are as follows:

Locality.	Direction.
East of Greensboro village	S 20 W.
Road to Craftsbury, 2 miles from north end of lake	S 20 E.
West of East Hardwick	S 20 W.
Prospect Hill, Craftsbury	S 20 W.
Prospect Hill, Craftsbury	S 40 W.
Eastern part of Woodbury, road to Cabot	S 60 W.
Eastern part of Woodbury, road to Cabot	S
Eastern part of Woodbury, road to Cabot	S 25 E.

PLATE XXXI.

BOULDER OF ORBICULAR GRANITE.

Locality.	Direction.
One mile north of Greensboro, road to Glover	S 20 W.
One mile north of Greensboro, road to Glover	S 20 E.
One mile north of Greensboro, road to Glover......	S
South side of Robeson Mountain	S 30 W.
South side of Robeson Mountain	S
South side of Robeson Mountain	S 30 E.

The above records have not been corrected for magnetic declination.

Striations recorded by the Hitchcock and Hager report on the Geology of Vermont.[1]

Locality.	Direction.
Glover	S 5 W.
North part of Greensboro	S 10 W.
Greensboro on Craftsbury line	S 10 W.
Greensboro, northern part	S
Craftsbury	S 10 E.

In the report on the Terranes of Albany, by C. H. Richardson and M. C. Collester, striations are recorded as being nearly south and south 20 west.[2]

GLACIAL BOULDERS AS INDICATIVE OF THE DIRECTION OF THE FORMER ICE MOVEMENT.

In case it is possible to establish the exact locality of a certain rock and boulders of the same kind are found distributed at various points to the south, these boulders may be said to indicate the direction of the former ice movement. Probably no other lithologic formation in Vermont is better suited for this purpose than the orbicular granite from Craftsbury. The only outcrop of this particular phase of granite occurs in the southeastern part of Craftsbury village. The rock is a biotite granite in which there is an excess of the mica and it has segregated into rounded masses often more than an inch in diameter. (Plate XXXI).

Boulders of the material are scattered through the drift in the area traversed. The following locations will serve to establish the directions. The occurrence of several of these boulders in the Eligo Valley from Cascade Creek to Little Eligo Pond indicates that they were brought there by the ice when it was moving in the direction south 30 degrees west. There is a boulder of this material just above the poorhouse in the town of Hardwick. This is indicative of the southerly movement of the ice. Still another of these rocks is found in the Lamoille channel one mile above East Hardwick, and was brought there by the

[1]Hitchcock and Hager, Report on the Geology of Vermont, 1861, Vol. 1, pp. 67-77.

[2]Richardson, C. H. and Collister, M. C.: The Terranes of Albany, Vermont. Eighth Report of the Vermont State Geologist, 1911-1912, p. 185.

ice in its movement south 20 degrees east. The directions taken by these boulders may be subject to variations as were the striations; nevertheless, they indicate the general movement.

Boulders of the Craftsbury granite are found in Washington and Orange, Vermont, indicating a southwest movement. A question as to lithologic character might present itself, as there is a less pronounced phase of the orbicular granite in which the discs or masses of biotite are often flattened, elongated and less numerous, that occurs in Northfield and Bethel, Vermont.[1] However, the erratics found in Washington and Orange could not have come from that locality, because the ice movement was not east and west.

Boulders of other lithologic formations might be used for this purpose, but it is difficult to be certain of their original habitat.

LAKES.

All lakes and ponds in the area, with the possible exception of Hardwick Lake and a few small ponds, are of glacial origin and indicate youthful topography. The township of Greensboro has four ponds and one lake. Hardwick has one artificial lake, three small artificial ponds and five natural ponds. Woodbury has in all 32 lakes and ponds, all of which are of glacial origin. This makes a total of 46 lakes and ponds for an approximate area of 120 square miles.

These bodies of water in Greensboro lie in a belt stretching from the northeast to the southwest corner of the township with their longer axes parallel and extending in a northerly and southerly direction corresponding to the direction of the ice movement. In most instances, they occupy pre-glacial limestone valleys that have been scooped out and deepened and are held in by the deposition of morainal material across the depressions in which they lie.

Horse Pond is circular in form and has a length of about 50 rods and a depth of 4 to 8 feet. It is situated in the northeastern corner of Greensboro, near the Stannard line, and at one time received the waters from the now extinct pond in Glover known as "Runaway Pond." Its outlet is to the south and forms part of the headwaters of the Lamoille River.

Mud Pond is located about a mile and a half northwest of Horse Pond and southeast of Paddock Hill.[2] This pond is about 200 rods long and 100 rods wide and has its outlet into the Lamoille two miles north of East Greensboro. This pond is rapidly filling with vegetation so that in the lower end there is

[1] Richardson, C. H.: Areal and Economic Geology of Northwestern Vermont. Fifth Report of the Vermont State Geologist, 1905-1906, p. 108.

[2] Richardson, C. H., and Turner, H. G.: The Terranes of Greensboro, Vermont. Ninth Report of the Vermont State Geologist, 1913-1914, pp. 281-282.

only a narrow strip of free water having a depth of about ten feet. This is an excellent example of a pond that is characteristic of youthful topography and also one that is being destroyed by one of the many agencies that make lakes and ponds short-lived features of our landscape.

Long Pond lies in the north central part of Greensboro just south of Wilson Hill.[1] This body of water is about one and a half miles long and a little more than a half mile wide at its widest place. Its waters flow into the Lamoille at East Greensboro.

Caspian Lake, situated in the south-central part of Greensboro, is a beautiful expanse of water two miles long and more than a mile wide.[2] This lake, celebrated for its clear cold waters, for the charming scenery that surrounds its shores, was formerly known as Lake Beautiful. Unlike the bodies of water thus far described, Caspian Lake does not lie entirely in a bed of limestone and phyllite. The northern shore is composed of several granite outcrops which are separated by limestone valleys. The east and west shores, down as far as Burlington Point, are also made up of granite intrusions between which are limestone valleys. The lower part of the lake lies in a synclinal trough of limestone which has been deepened and widened by the effects of glaciation.

The lake is held in by a deposit of morainal material and by an artificial wall with narrow flood gates at its outlet into Mill Branch. Greensboro Village is located on Mill Branch about two hundred yards south of the lake and is about 20 feet lower. This condition, together with the steep gradient of Mill branch, gives abundant waterpower for the mills of the village.

There are many good farms near the lake and it is also situated within two miles of the St. Johnsbury and Lake Champlain Railroad so that it has become one of the foremost summer resorts of northern Vermont.

Eligo Pond lies in the southwestern part of the town and the northern end extends into the edge of Craftsbury.[3] This pond forms the headwaters of the Black River. It is about one and one-half miles long and about 100 rods wide, and lies at or near the contact of the Cambrian and Ordovician terranes. Little Eligo lies along the same line of contact a short distance south and a greater part of the pond lies in the town of Hardwick. It is about 50 rods long and 20 rods wide, and forms the headwaters of Alder Creek.

In Hardwick the natural bodies of water are small and unimportant. There are two ponds in the northern part of the township. One of these is known as Tottie Pond and lies near

[1] Richardson, C. H., and Turner, H. G.: The Terranes of Greensboro, Vermont. Ninth Report of the Vermont State Geologist, 1913-1914, p. 281.

[2] Idem, p. 282.

[3] Richardson, C. H., and Turner, H. G.: The Terranes of Greensboro, Vermont. Ninth Report of the Vermont State Geologist, 1913-1914, p. 281.

the Greensboro line. Both of these ponds lie in limestone with their longer axes in a north and south direction, suggesting that they have been influenced by glaciation.

There are three small ponds or reaches along Cascade Creek on West Hill. They mark successive levels in a hanging valley.

Dams have been constructed on Nichols Pond brook in two places; one at Mackville, and the other about one-half mile farther up the stream. The pond at Mackville furnishes power for the lighting plant at Mackville, while the one above furnishes power for a saw-mill and may be used as an auxiliary reservoir for the waterpower at Mackville.

There is a dam across the Lamoille at East Hardwick, forming a pond about 100 rods in length, which furnishes ample water power for the mills at that place.

The only lake in Hardwick is situated a little west of the village of Hardwick, in the Lamoille and Alder Creek valleys.[1] The lake is about two miles in length and a half mile in width. It is artificial in origin and was constructed to provide a reserve for the electric light plant on the Lamoille in Wolcott.

In the town of Woodbury, there are 32 natural lakes and ponds, but only a few of the most important ones will be described. Most of them lie in the limestone area in the southeastern part of the township. These bodies of water, like those of Greensboro and Hardwick, have their longer axes in the direction of the former ice movement and lie for the most part in valleys that have been scooped out and deepened by the glacier.

The only lakes in the township that do not drain south into the Winooski basin, are Pickett's Pond, East Long Pond, and Nichols Pond in the northeastern, and Slayton Pond in the southwestern, part of the town.

Pickett's Pond is situated a little southeast of Robeson Mountain and has its bed in granite. This and one other very small pond about one mile to the east form part of the headwaters of East Long Pond.

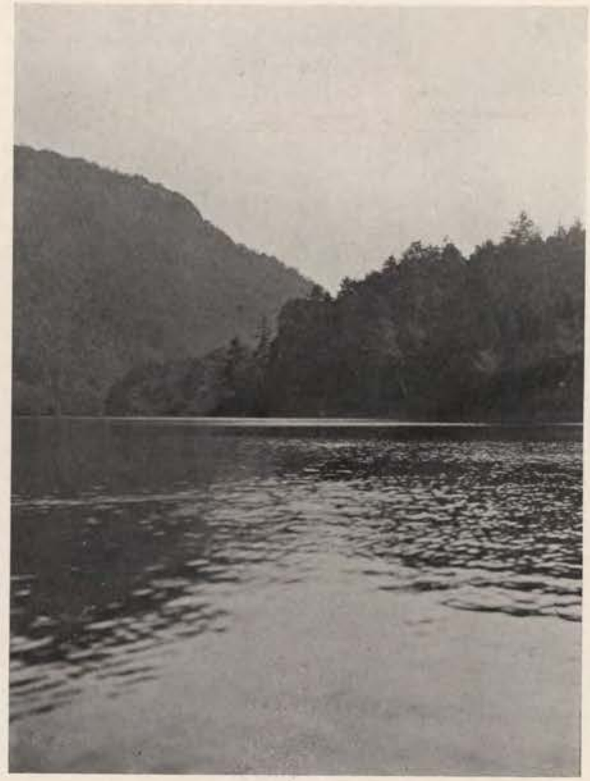
East Long Pond is about one and one-half miles long and three-quarters of a mile wide.[2] It is situated northeast of Robeson Mountain and its bed lies in granite on the west and in the Ordovician limestones and phyllites on the east. East Long Pond has its outlet to the north into Nichols Pond.

Nichols Pond, a body of water about three-quarters of a mile in length and half a mile in width, is situated in the northeastern part of Woodbury at the base of Nichols ledge.[1] This ledge or cliff, with its bold vertical face, rises up more than 200 feet above the surface of the pond. It is composed of both

[1] Richardson, C. H., Brainerd, A. E., and Jones, D. J.: Geology and Mineralogy of Hardwick and Woodbury, Vermont. Ninth Report of the Vermont State Geologist, 1913-14, pp. 302-303.

[2] Richardson, C. H., Brainerd, A. E., and Jones, D. J.: Geology and Mineralogy of Hardwick and Woodbury, Vermont. Ninth Report of the Vermont State Geologist, 1913-14, p. 303.

PLATE XXXII.



WOODBURY MOUNTAIN FROM GREENWOOD LAKE, WOODBURY igneous and sedimentary rocks. A most beautiful view can be obtained from the top of this cliff, and were it not for their inaccessibility, both East Long Pond and Nichols Pond would be prominent resorts for summer tourists. The outlet is to the north into Nichols Pond brook, where there is a dam to provide water power for a mill at that place, and also to act as a reserve for the power plant at Mackville in the township of Hardwick.

Slayton Pond is situated in the southwestern part of the township on the west side of the Cambrian hills.[1] It is about 200 rods long and 150 rods wide and its bed is in the Cambrian sericites and quartzites. The outlet is to the west into the township of Elmore thence in a northerly direction into the Lamoille river.

Buck Lake is located about one mile northwest of Robeson Mountain and is situated in the same granite area as Nichols pond.[1] It is about 250 rods long and 100 rods wide. The area around the lake is thickly wooded, which makes it impossible to see it from a distance. The lake is also located in the vicinity of some excellent granite quarries. Its outlet is to the south into the Winooski basin. (Plate XXXII).

Greenwood Lake, or West Long Pond as it was formerly called, is located about one and a half miles northwest of Woodbury.[2] It is about a mile long and a half mile wide. The shore line is very irregular and there are two small islands; one near the south end, the other near the west side about midway of the lake. The lake lies entirely in the limestones and phyllites and has its outlet to the south through a chain of five very small ponds into Woodbury Lake. One of these ponds located about one-half mile northwest of Woodbury Village, known as Pickerel Pond, is held in by a dike of igneous rock which forms a very effective dam.

Valley Lake, formerly known as Dog Pond, is located in the same depression as Greenwood Lake, about one-half mile to the southwest.[3] The two lakes are separated by a low ridge of glacial debris. The shore line of this beautiful sheet of water is very irregular, but some of the indentations are being rapidly filled with vegetation which has resulted in the formation of quaking bogs. The lake is about three-quarters of a mile long and nearly a half mile in width. It lies partly in a bed of limestones and partly in a belt of slates whose planes of fissility have formed a nearly vertical cliff on the east shore, 75 to 100 feet in height. The outlet is to the south through a chain of two small ponds into Woodbury Lake, a short distance west of the outlet of Greenwood Lake.

[1] Richardson, C. H., Brainerd, A. E., and Jones, D. J.: Geology and Mineralogy of Hardwick and Woodbury, Vermont. Ninth Report of the Vermont State Geologist, 1913-14, p. 305.

[2] Idem, p. 304.

[3] Richardson, C. H., Brainerd, A. E., and Jones, D. J.: Geology and Mineralogy of Hardwick and Woodbury, Vermont. Ninth Report of Vermont State Geologist, 1913-14, p. 304.

Mud Pond in the southeastern part of the township is about 60 rods long and about 40 rods wide. It lies in a bed of limestone and has its outlet to the west into the outlet of Greenwood Lake, thence to Woodbury Lake.

Woodbury Lake, formerly known as Sabine Pond, is located on the southern border of the township, about three-fourths of a mile south of South Woodbury, and part of the lake extends into the township of Calais.[1] The lake is about 400 rods long and 200 rods wide, and the bed lies in the Ordovician limestones and phyllites. There are some very fine delta deposits along the east and north sides, where small streams have deposited sediments in the lake basin. The scenery around the lake is very beautiful and some of the best farms of the township are located along the shores, making a very desirable spot for a summer camp. The outlet of this pond is south into the Winooski River.

Nelson Pond is situated in the southern part of Woodbury nearly a mile west of Woodbury Lake.[2] This body of water also lies partly in Woodbury and partly in Calais. Its bed is entirely in the limestones and interbedded phyllites. There are two small ponds to the north whose waters flow into Nelson Pond, one of which is a small pond known as Cranberry Meadow Pond.

There are several other small ponds within the area and many of them are rapidly disappearing because of the abundant vegetation and sediment that are collecting in them.

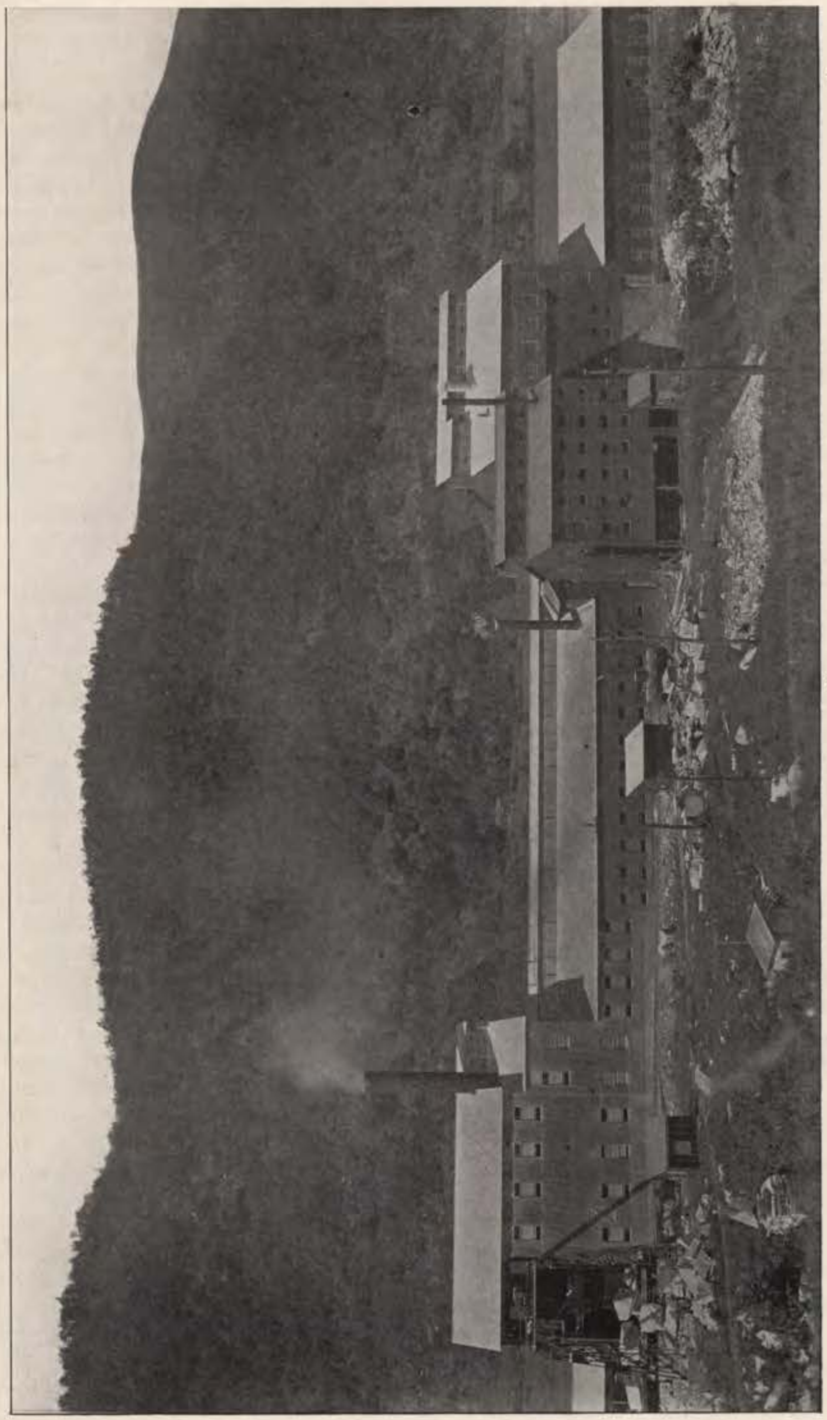
Lakes and ponds are formed in many ways. Any depression below the water table may fill with water. The cutting off of meanders in rivers may result in the formation of oxbow lakes. Diastrophic movements cause depressions which may become filled with water. Most lakes of the world are a result of glaciation and may have been formed by the damming up of valleys with morainal material, scooping out of depressions, irregularities in the drift, etc.

As soon as a lake comes into existence, there are several agents that combine in an effort to destroy it. Some of the causes for the destruction of a lake are as follows. Sediment is brought in by inflowing streams and a corresponding amount of water is displaced. Skeletons of animals help to fill the basin of the lake. Mineral matter is often deposited in the lake basin especially when evaporation exceeds the inflow. Dying vegetation fills many lake basins, resulting in the formation of peat deposits. The greatest enemy to the existence of lakes is the cutting down or lowering of their outlets so that they are ultimately drained. Thus, it is seen that lakes are constantly changing and have a comparatively short existence. For these reasons they

[1] Richardson, C. H., Brainerd, A. E., and Jones, D. J.: Geology and Mineralogy of Hardwick and Woodbury, Vermont. Ninth Report of the Vermont State Geologist, 1913-14, p. 304.

[2] Idem, pp. 304-5.

PLATE XXXIII.



LIME PLANT OF VERMONT MARBLE COMPANY, WEST RUTLAND.

are regarded as an evidence of youthful topography and are said to be the most short-lived features of the landscape.

The life history of the lakes and ponds of this area is as follows: the continental glacier has scooped out depressions, widened and deepened valleys and thrown deposits of morainal material across them, which holds the water in check. In glacial times or directly after, these lakes and ponds were much larger than at the present time. Directly following their formation, they began filling with sediment and vegetation. Their outlets probably have been lowered to a considerable extent. As a result there are lakes in all stages of preservation. Mud Pond in Greensboro represents a pond that is rapidly filling with vegetation. Many places in the vicinity of Greenwood Lake show depressions in the morainal material that have been completely filled with sediment, mud, and vegetation, which shows how a lake or pond is completely destroyed.

SUMMARY.

In making a detailed physiographic study of the townships of Greensboro, Hardwick and Woodbury, the writer has observed the following:

1. The east and west boundary lines of the townships extend in a direction north 40 degrees east, corresponding to the general strike of the underlying sedimentaries.
2. The sand terraces were laid down while a glacial lake of considerable extent covered the area.
3. The major valleys of the area were widened and deepened by glaciation and extend for the most part along the line of strike of the underlying terranes.
4. The pre-glacial drainage, as nearly as can be determined, was similar to the present drainage system.
5. If the water level of Eligo Pond should rise three feet, the pond would have an outlet to the south as well as to the north, because of the fact that the col on the south is very low. Moreover, there is evidence in the form of terraces showing a southern drainage of glacial Lake Memphremagog through this gap.
6. No part of the area traversed had sufficient altitude to escape the action of the continental glacier.
7. A portion of the terminal moraine in Woodbury takes the form of a kettle moraine.
8. There are three distinct directions taken by the glacier in its southward movement, as indicated by glacial striations.
9. Boulders of the orbicular granite of Craftsbury, radiating in a southerly direction from its only known outcrop indicate the general direction of the ice movement.

10. All the natural lakes and ponds of the area are glacial in origin and most of them have their longer axis extending in a northerly and southerly direction corresponding to the general ice movement.

11. The area is one of typical youthful topography.

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DESCRIPTION OF THE NEW LIME PLANT OF THE VERMONT MARBLE COMPANY AT WEST RUTLAND.[1]

HAROLD LADD SMITH.

OUTLINE.

A. Difficulties previously encountered in making lime from crystalline limestone.
B. The rotary kiln and its development.
C. The West Rutland rotary kiln plant.
    I. Crushing and storing raw material.
    II. Burning and storing quick lime.
    III. Hydrating and bagging of lime.
    IV. Storage.
    V. Miscellaneous data.
D. The rotary kiln an asset to Vermont Industries.
    I. The nature of a rotary kiln product.
E. The products of the West Rutland plant.
    I. Pulverized stone.
    II. Oxide or quick lime.
    III. Hydrated lime (Hydrate).
        a. Definition and general characteristics.
        b. Hydrate in the mason's field.
            1. Advantages of its use and comparison with quick lime.
        c. Hydrate in the waterproofing field.
            1. Advantages of its use.
        d. Hydrate in the agricultural field.
            1. Comparison with pulverized stone and quick lime.
        e. Hydrate in the chemical field.
            1. Advantages of its use.
        f. The future of hydrated lime.
            1. The appeal to the average user.
            2. Gain in sales.

[1] The recently established lime plant at West Rutland is so unlike any other in the State and so interesting in itself that Mr. Smith of the Vermont Marble Company was asked to prepare for this Report an account of the equipment.

The Company has supplied the illustrations which are used in the article and which add greatly to its value.

The Lime Industry is by no means a new one for the State of Vermont because for many years the old style vertical kiln has turned out a product from our limestone deposits which has made "Vermont Lime" famous and in great demand throughout New England. A large portion of the limestone deposits in the State, however, is of the highly crystalline formation that has made the Vermont marble industry what it is today and the many attempts to make this marble into lime in a vertical kiln have heretofore met with failure. The difficulty encountered in each attempt has been that the highly crystalline limestone has, upon the application of heat, broken into granular form instead of keeping its shape as is the result in burning the ordinary limestone to lump lime. The very natural result of the breaking down into this granular form was that the draft of the vertical kiln was choked, the burning stopped and the attempt an absolute failure.

The rotary kiln proved a solution to this problem and opened a way for the Vermont Marble Company to utilize at least a part of its waste product in the manufacture of lime. The development of the cement industry had demonstrated the possibilities of the rotary kiln but only very recently has the principle been applied to the manufacture of lime. As early as 1885 the rotary process for burning lime was tried but only within the last ten years has this method of lime manufacture been on a commercial basis. A few plants of this nature have been operated successfully but not until the present year has this new method of manufacture become one of Vermont's industries.

We give herewith a detailed description of the present equipment and method of manufacture of the rotary kiln lime plant recently completed at West Rutland where the Vermont Marble Company is manufacturing its Vermarco Quick and Hydrated Lime. The main steel building, 48'x422', with two other buildings 30'x48' and 20'x32' housing the gas producer equipment and coal storage, are illustrated in the cut herewith. The construction is structural steel frame throughout on concrete foundations and covered with corrugated iron siding and roofing, making a building of a most permanent type and absolutely fireproof.

The cars loaded with blocks, spalls or any suitable class of marble waste from the quarries and mills are delivered under a crane runway equipped with a twenty-five ton electric crane and this equipment unloads the raw material and delivers it to a 48"x60" Superior jaw crusher. (See Figure 3). This crusher weighs 105 tons and is operated by a one hundred and fifty horse power motor. The swinging jaw moves only about three or four inches but this is sufficient to crush any block that will go into the four by five foot opening, at the rate of two hundred forty tons an hour or four tons a minute. So great is the momentum gained by this huge crusher and its fly wheel that it will run for about five minutes after the power is shut off.

PLATE XXXIV.

LIME KILN.

These chunks of marble that are discharged at the bottom slide directly into a gyratory crusher (see Figure 4). When it is found desirable to unload mill or shop waste or other material small enough to go direct to the gyratory crusher, the dump cars discharge their load to this crusher without the crane handling it or its passing through the jaw crusher. The crushed stone is then elevated and discharged by a conveyor into two stone storage bins which permit a forty-eight hour supply of raw material ahead of the kiln.

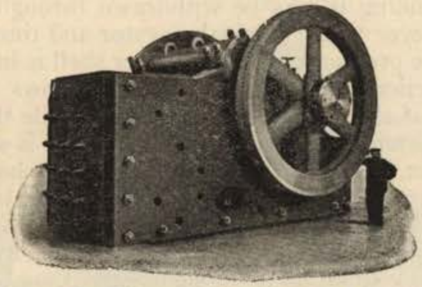


FIGURE 3. 48" x 60" Superior Jaw Crusher.

The kiln (see Plate XXXIV) which measures eight feet in diameter by one hundred twenty feet long and resembles a huge stack on its side was built by the Vulcan Company. It is constructed of ⅝" steel plates and the kiln equipment complete weighs 118 tons. It is lined with fire brick and revolves on two

FIGURE 4. Gyratory Crusher.

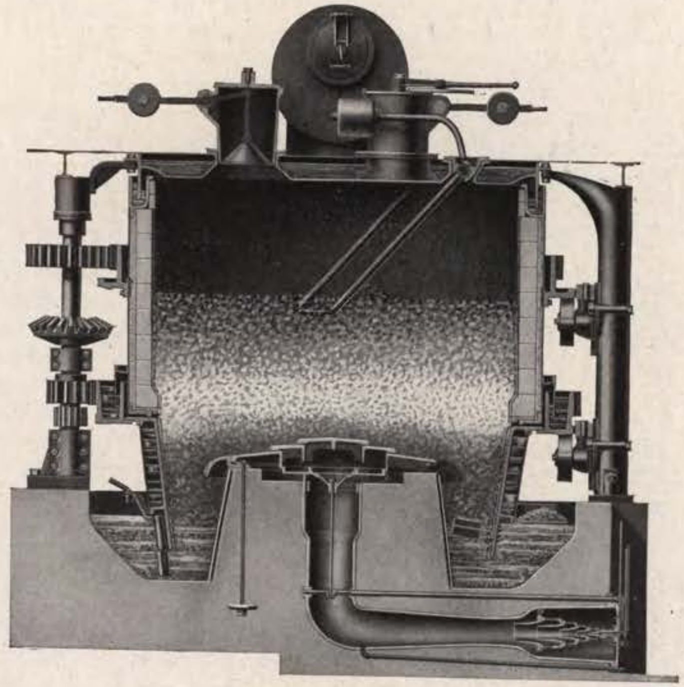
bearings at the rate of about one revolution every three minutes, a thirty horse power variable speed motor furnishing the power. This motor regulation enables the speed of the kiln to be adjusted to suit the conditions of burning and the feed is operated by a rope drive on the same motor so that any change in speed of the kiln automatically changes the rate of the feed of the crushed stone to the kiln.

The heat for burning is furnished by a Chapman mechanical ten foot gas producer (see Plate XXXV) situated in a separate building. The incoming fuel is dumped through the car bottoms into a hopper under the track from which it is conveyed to coal crushing rolls. This crushed coal is elevated and discharged directly into the coal bin over the gas producer or into the large concrete storage building with a capacity of about 300 tons. From this storage building it may be withdrawn through tunnel gates and a belt conveyor to the original elevator and thus taken to the coal bin over the producer. The producer shell is in two sections. The bottom section, to which are fastened plows for the automatic removal of the ashes, revolves slowly while the top section revolves at a faster rate of speed. The twyere is stationary and through it a jet of steam is admitted. A mechanically water cooled poker fastened in the stationary top, aided by the circular motion of the shell, keeps the mass of the fire agitated and compact. The whole is water sealed and has a capacity of gasifying about one ton of coal an hour. One pound of coal when gasified will produce from three to five pounds of lime, depending on the quality of the gas and the character of the stone. From the producer the gas is conveyed to the main building in a large steel flue, varying from three to four feet in diameter, and delivered into the lower end of the kiln where it ignites, producing a temperature of about twenty-two hundred degrees Fahrenheit. A Westmoreland County gas coal is used in this process, the requirements being that the coal must contain not over one per cent. of sulphur and be very low in ash.

The kiln is set at a pitch of one-half inch to the foot. It can thus be readily seen that the mass of broken marble being admitted at the upper end will gradually travel toward the lower end—it taking about four hours to pass through. Surface moisture is driven off early in the kiln and as the stone approaches the lower end the pieces are broken down and the balance of any moisture (H_2O) and the carbon dioxide gas (CO_2) is driven off and carried with the combustion gases up the stack. The actual burning of the limestone is probably limited to the last or lower thirty feet in the kiln known as the burning zone. The reaction is a simple one;—$CaCO_3 + \text{heat} = CaO + CO_2$. A series of baffling walls in the stack chamber prevent the fine stone particles and lime from being drawn up the stack by the draft and any of this material which collects at the base of the stack chamber is removed by a screw conveyor to the original stone elevator and deposited in the stone bins, thus being returned to the kiln.

The lime oxide or burned lime discharges at the end of the kiln through a chute directly into a cooler situated at a lower

PLATE XXXV.



GAS PRODUCER.

level in the cooler pit. This is a stack-like cylinder on its side similar to the kiln but without any brick lining and measures five feet in diameter by fifty feet long. The cooler equipment weighs about 27 tons. Lifting angle irons are bolted to the inside of the cooler so that as it revolves the fine granular lime is raised and dropped through the air and thus the cooling operation is facilitated. A draft through the cooler is induced by the kiln stack and the burning process in the kiln and thus the air passing over the hot lime in this cooling process is preheated for the kiln. This cooler is mounted on two bearings pitched at the same grade as the kiln and operated by a ten horse power motor. The granular lime which entered the cooler at approximately twenty-two hundred degrees is discharged at the end sufficiently cooled so that it can be safely elevated to the two large steel oxide bins of approximately two hundred fifty tons capacity each. From these bins the quick lime can be loaded in bulk into cars or barreled as the trade demands. Automatic scales are being installed to control both operations. In a cooperage shop connected with the plant the barrels are made, in which the oxide is packed.

From these bins the lime oxide may be taken by still another elevator to the six cylinder Kritzer hydrator. (See Plate XXXVI) This machine scientifically slakes the lime adding the proper amount of water to exactly hydrate and yet have the product come out absolutely dry. The water is admitted in a spray to the stack of the hydrator through which the heat generated by the chemical reaction is carried off and this not only keeps the light hydrate from being drawn up the stack but the water in turn is preheated thus assisting the action of hydration. Revolving beaters or paddles assist the movement of lime and water through the series of six cylinders thoroughly mixing the oxide with the water and insuring complete hydration and absolute drying so that the material is discharged to a screw conveyor at the bottom as an impalpable flour. This passes to Raymond mills and beaters where any core, unburned material or foreign substance of any kind is separated and discharged permitting the pure, white, fluffy hydrate to be raised in the air separators to the hydrate storage bins from which it is bagged in valve paper sacks by an Urschell-Bates valve bagging machine, (see Plate XXXVII). A dust collecting system at the bagger removes the fine material that is spilled in bagging. This bagger works in a unique way. The paper sacks are made with no opening except for a small hole in a fold at one end. Through this hole a tube about one inch in diameter is inserted and through this the hydrate is forced into the bag. The flow of hydrate is automatically stopped when the bag contains fifty pounds. No sealing or tieing of the bag is necessary for the pressure of the contents seals the opening in the fold and then the bags are trucked and piled in the stock house.

The large storage space at the end of the building permits carrying a stock of both the oxide and hydrate. The ability to store from 1,500 to 2,000 tons of lime guarantees prompt deliveries and economic operation.

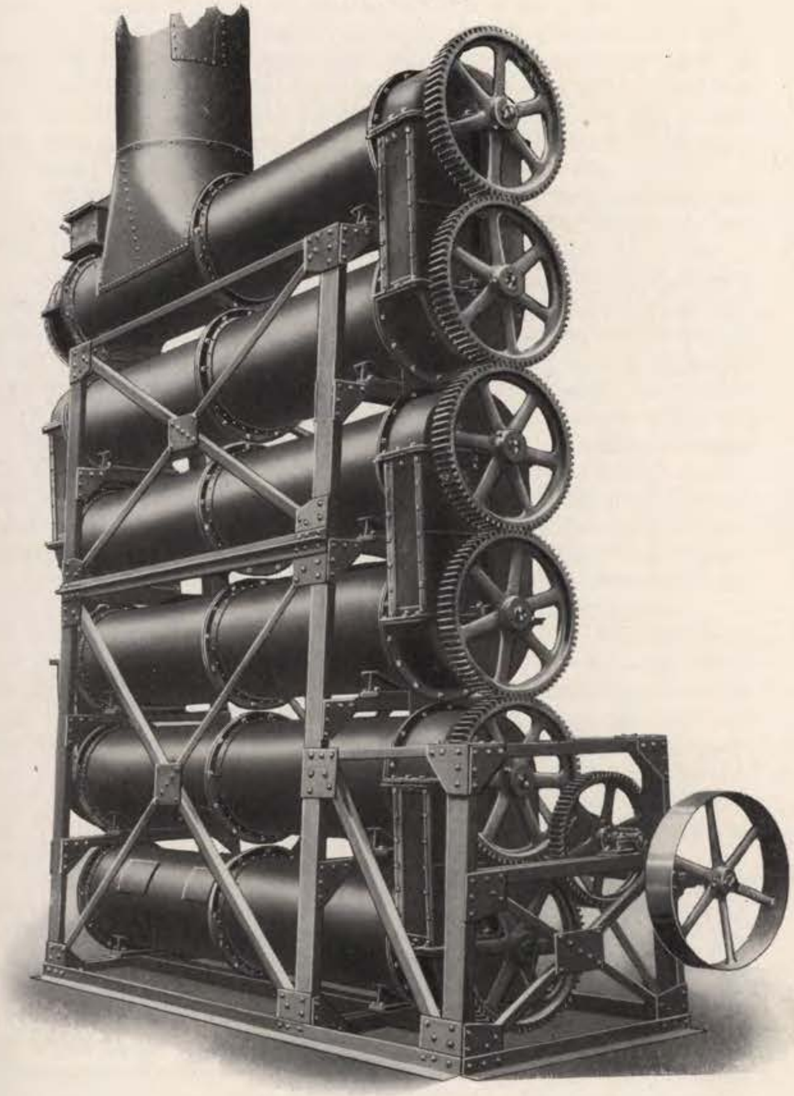
Work is already under way to add to the equipment above described a pulverizing stone department which will take the crushed marble from the stone storage bins and with the aid of a Fuller mill, will reduce it to about one hundred mesh product suitable for agricultural limestone, as a paint and putty filler, etc., for which the demand is rapidly increasing. This product will be elevated to storage bins, packed and shipped in a way similar to the lime products.

The entire plant has been so designed that its capacity may be doubled for space has been left for the installation of another kiln, cooler and producer as soon as growth of business demands. Individual motors control each operation, the electric power being supplied from the Company's hydro-electric stations. The capacity of the plant as it is now equipped is about 60 tons of oxide a day or 75 tons of hydrate. The operation is continuous night and day except for enforced shutdowns for repairs. As many operations as possible have been made automatic thus reducing to a minimum the item of labor.

The rotary kiln lime plant is an especially valuable addition to Vermont industries since it makes it possible to burn our Vermont crystalline marble deposit which cannot be burned in the old style vertical kiln—thus providing a market for a part of the great waste item in the marble industry.

The product of the rotary lime kiln is granular and therein lies the greatest difference from the lump quick lime with which everyone is familiar. Quick lime (CaO) upon exposure to the air takes up chemically the moisture of the air (H_2O) and the carbon dioxide (CO_2) resulting in a product that is partly hydrated lime ($Ca(OH)_2$ and partly carbonated lime ($CaCO_3$). In so combining it breaks down to granular form and because of the large percentage of the lime that has reverted to the original limestone ($CaCO_3$) it is of little value to the mason. It is not strange, therefore, that the general public should draw the conclusion that a lime that is granular in form is air slaked. Familiarity with the product however soon demonstrates that this is not the case. Actually because of its compact form, very similar to granulated sugar, the Vermarco lime will not air slake as readily as a lump lime but it hydrates with greater rapidity than lump lime for the water has immediate access to each particle.

PLATE XXXVI.



KRITZER HYDRATOR.

The products of this plant are pulverized limestone for agricultural uses—the oxide or quick lime and the hydrated lime both for building, chemical and agricultural purposes.

The pulverized stone department and its products for agricultural uses we will pass over since they are not essentially a part of the rotary kiln plant in which we are especially interested in this article. Suffice it to say that the equipment will enable the company to meet the big and growing demands for agricultural limestone.

Some explanation of the hydrate and its uses however as compared with the usual quick lime will be quite fitting at this time.

The question may rightly be asked,—What is hydrated lime? Hydrated lime is ordinary quick lime (lump lime or oxide) whose affinity for water has been satisfied—it is slaked lime with the surplus water driven off leaving a dry, impalpable powder resembling flour. It possesses the following noticeable characteristics. It can be safely stored without the fire risk that is always present with ordinary quick lime. Insurance companies make a substantial reduction in rates to the dealer stocking hydrate instead of quick lime. Unlike quick lime it will keep almost indefinitely since it will absorb no more water (H_2O) and the action of the carbon dioxide (CO_2) in the air is almost negligible. Hydrated lime is so fine that 99.5% will pass a 100 mesh screen or 98% will go through a 200 mesh screen. It should be borne in mind that 200 mesh means 40,000 openings per sq. in. This is much finer than cement of which only 75% to 80% will pass a 200 mesh screen and the importance of this fact will be pointed out later. Hydrated lime is purer than the quick lime from which it is made for all impurities have been removed. It should be emphasized that hydrated lime can be used wherever quick lime is used for practically all quick lime is actually utilized in the putty form which is simply a mixture of hydrated lime and water.

Some of the advantages in the use of hydrate in the mason's field for plaster and cement mortar are as follows:—All quick or lump limes vary considerably, even the different burnings of the same make differing widely, thus introducing an uncertain factor that is ever present in the use of lump limes. This variation and the different handling by each mason introduces a feature of uncertainty in the slaking of quick lime. These facts together with the necessity of curing quick lime plaster have more than anything else driven the lime plasters from their rightful field and the gypsum hard wall plasters, of known constant characteristics, have taken their place. Hydrate,—on the other hand, runs constant and even hydrates of different makes are remarkably similar. The architect no longer needs to hesitate to specify lime for plaster because of non-uniformity of the product or the varying preparation of the mason, since with the hydrated lime the plaster is prepared by an unvarying formula.

Quick lime plaster must be prepared and cured before application to the wall. This necessitates considerable space for mortar beds and curing barrels which in the city is quite a feature of expense. The natural tendency in trying to hurry the plastering in a building is to use the plaster before it is properly cured which often results in pitted or popped walls because the lime has not thoroughly slaked.

A high grade hydrated lime plaster on the other hand may be applied the same day that it is mixed although its plasticity is increased by letting it stand over one night. Even when applied immediately there is no danger of pitting and thus much valuable space and equipment is saved. It is estimated that the cost of slaking lime on the job sometimes runs as high as $2.00 a ton, which expense is saved by the use of hydrate.

Despite efforts to wet down bricks before laying they absorb the moisture from the mortar often to a harmful extent. When hydrated lime is added to a cement mortar it carries increased moisture to a marked degree thus insuring the retention of sufficient water to properly hydrate or set the cement.

A hydrated lime cement plaster possesses a peculiar plasticity enabling the mason to cover more surface in a given time with less effort.

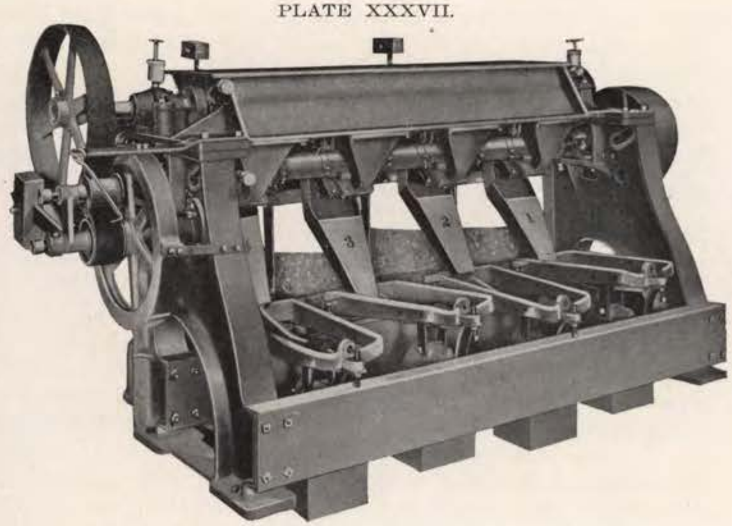
Hydrated lime is shipped in 50 lb. paper sacks which are easily destroyed on the job and are a considerable saving in cost as compared with the barrel expense necessary in handling quick lime.

Probably the most revolutionary feature of hydrated lime is its use as a waterproofing agency and as an important ingredient of all concrete and cement work. The addition of from 10 to 20% of hydrated lime to concrete cement work has the following important results. It increases the plasticity and homogeneity of the mass causing concrete to flow more readily into place and to increase the covering capacity and spreading quality of cement. This is important in construction work for concrete containing hydrated lime will flow through a chute at a lower inclination than without it and thus necessitate fewer distributing points.

The tendency toward segregation in concrete is reduced to a minimum by the presence of hydrated lime. This ever present danger is that the sand and gravel will separate from the cement, which is heavy and dense, forming a weak and porous job. This is especially true where mixtures are made overwet to aid flowing.

The addition of hydrated lime causes the retention of a sufficient amount of moisture in the concrete or cement plaster while setting. This aids the complete hydration of the cement and thus reduces the risk of shrinkage and cracking.

PLATE XXXVII.



URSCHELL-BATES VALVE BAGGING MACHINE.

Voids in concrete are prevented by the addition of hydrated lime,—making the mass less porous and more impermeable. Thus the finished job is not only waterproof but absorption, with the resulting expansion and contraction, is reduced to a minimum. Since the addition of hydrated lime does not increase the bulk—it is evident that it must fill the minute spaces or voids in the mass. Most waterproofing substances now on the market have an organic base—thus ultimately are subject to decay and disintegration. They may at first have a waterproofing effect but when they decay they leave the mass in a porous state. Hydrated lime being a mineral is not subject to this criticism and results in a homogeneous mass.

The strength of the mixture is increased by the addition of hydrated lime. The following tests with briquettes made with one part of cement and hydrated lime to three parts of sand demonstrate this fact.

Strength per sq. in.	7 days	28 days
1 part cement 3 parts sand	340 lbs.	433 lbs.
1 part (95% C. 5% H. L.) to 3 parts sand	356 lbs.	450 lbs.
1 part (90% C.10% H. L.) to 3 parts sand	390 lbs.	472 lbs.
1 part (85% C.15% H. L.) to 3 parts sand	365 lbs.	440 lbs.

Thus it is seen that there is no danger of weakening the completed work by the introduction of this waterproofing agency.

Agriculturally lime products (including pulverized limestone) benefit the land in three ways. *Chemically* they liberate plant food, making the phosphate and potash available and they correct the natural acidity of the soil. *Physically* they loosen heavy soils and aid sandy soils to hold moisture. *Biologically* they promote the development of bacteria in the soil. This permits the growth of legumes and thereby restores nitrogen to the soil.

Pulverized stone contains the same beneficial properties as the burned lime but they are not as available—the reaction is slower and it takes twice the bulk to accomplish the same results.

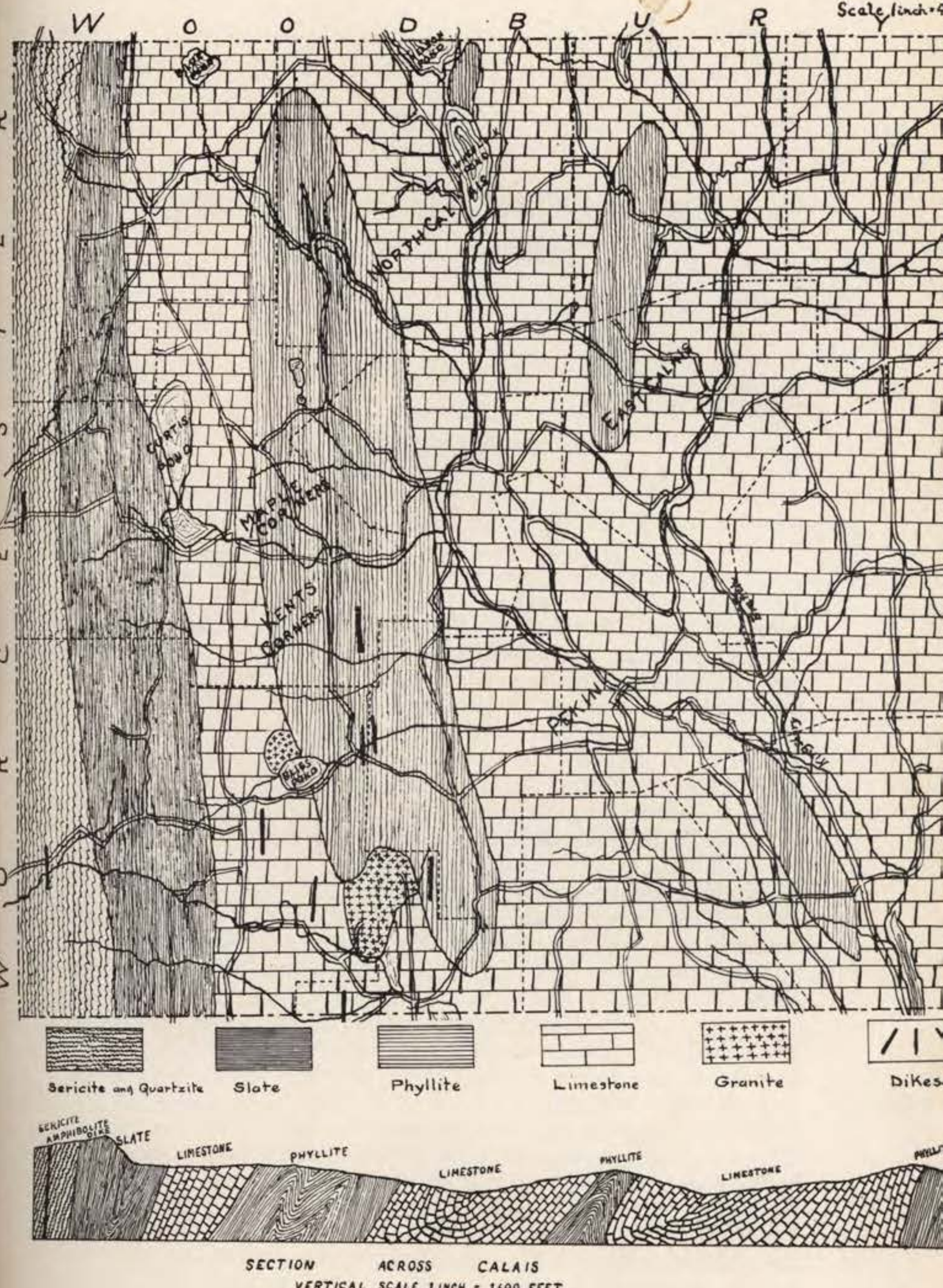
Quick lime is immediate in its action, concentrated but inclined to burn.

Hydrated lime is 100% efficient since it contains no inert foreign substances or unburned material and it does not dry out the soil or burn since its affinity for water has been satisfied. It will readily dissolve and pass into the soil.

As a chemical lime the hydrated form is by far the best. Tanneries, bleacheries, pulp mills, sugar refineries, etc., are all anxious to secure a lime with a high calcium content and free from all silica and foreign or unburned material. These qualifications are fulfilled in a high grade calcium hydrate.

The great advantage of hydrated lime that appeals to the average lime user or dealer is the fact that it keeps indefinitely. Many whose consumption has not been large enough to permit buying in carlots have been at the mercy of the local distributor and high prices. By the use of hydrated lime he may purchase in carloads with absolute safety and considerable saving. Sales of hydrated lime have made tremendous gains in the last ten years. Practically 500% more was sold in 1915 than in 1906 and eminent lime men predict that the hydrate will be the only commercial form of lime within a few years.

PLATE XXXVIII.



MAP OF CALAIS.

THE GEOLOGY OF CALAIS, EAST MONTPELIER, MONTPELIER AND BERLIN, VERMONT.

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INTRODUCTION.

The present report upon the Geology of Calais, East Montpelier, Montpelier and Berlin, Vermont, is of necessity very brief. It must be considered only as one of progress in the solution of the intricate geological problems in the eastern half of the State. The author traversed the area involved in this report in reconnaissance work in 1895 and in 1896, but it was not until the summers of 1915 and 1916 that any detailed study could be given to the field. In the earlier work the importance attached to this particular field was but little realized. In the later work the time available in two brief seasons has proven inadequate for a complete study of all of the field relations, the mapping with reasonable accuracy of the area involved without the aid of much needed topographic maps, the collection of museum specimens of the different types of minerals and rocks, the preparation of microscopic slides and the desired chemical analyses.

In the summer of 1915 the author was accompanied by E. C. Baker and E. S. Van Deusen and in 1916 by S. P. Poole and B. W. Roberts, all of whom were students in Geology and Mineralogy at Syracuse University. The aid of these men made possible the checking of a much larger number of details, and their assistance in the work was therefore extremely valuable.

The area chosen extends in a southwesterly direction some 25 miles from the township of Woodbury which was covered in my last report and published by the State Geologist in the Annual Report of 1914. The area also lies near the center of Washington County and a little to the north of the geographical center of the State. The east town lines are nearly parallel with each other but the line of East Montpelier is situated farther to the east than that of either Calais or Berlin. This difference is made apparent by a study of the accompanying maps. The west town lines are not exactly parallel and East Montpelier and Montpelier do not extend as far to the westward as either Calais or Berlin. These east and west town lines are approximately north 40 degrees east, and therefore nearly parallel with the average strike of the different sedimentaries involved in the area. A little work has been done in Marshfield, Plainfield and Barre on the east, Northfield on the south, and in Moretown, Middlesex and Worcester on the west.

There are three reasons for the selection of this area. (1) It lies south 40 degrees west from Woodbury where my work was finished for the summer of 1914. (2) It falls in the line of the erosional unconformity between the Upper Cambrian terranes and the Ordovician formations represented in the eastern half of the State. (3) The evidence obtained during the last few days of field work during the summer of 1914 of more abundant and better preserved fossils in these more southern townships. The last reason has been amply justified by the discovery of 33 hitherto unknown beds of graptolites during the past two summers. The more imporant localities will be described under the caption of Paleontology later on in this report.

One hundred and thirty-three new rock specimens have been collected during the last two summers thereby bringing the total number of specimens secured for the State Museum from the eastern half of the State to seven hundred and sixty. One of these specimens is a slab of shaly limestone which is well covered with crushed graptolites. This specimen was obtained from the north side of Berlin Mountain, Berlin, Vermont. From the various samples collected over one hundred microscopic slides have already been prepared for detailed study and material for nearly as many more slides is still in my possession. I had hoped that the petrographic paper now in the process of preparation would be available for the present report but the time is too limited for the amount of work that must be done.

Many photographs have been taken in this field, a few of which appear as half-tones in this article. Three maps accompany this report. They are areal, showing the geographic distribution of the terranes within the area involved. Beneath the map of each township there is a cross-section of the rocks. These sections are drawn across the townships from east to west. In each case they are drawn nearly midway between the north and south lines and at right angles to the strike of the sedimentaries. It will be noticed that no cross-section appears for the City of Montpelier as such for the section across East Montpelier traverses a part of the present City of Montpelier.

I wish to recognize my great indebtedness to Dr. Rudolf Ruedemann, State Paleontologist, Albany, N. Y., for his services in the identification of graptolites from the limestones and slate from each township represented in this report, and for examination of other forms strikingly suggestive of fossils. Some of the

PLATE XXXIX.

SAND AND GRAVEL PIT, NORTHFIELD STREET, MONTPELIER.

material collected this summer is still in the hands of Dr. Ruedemann, and doubtless his reply will be returned in ample season to be included in the paleontological division of the report.

It is a source of great satisfaction to have found these true diagnostic features of age, either in the limestones or in the interbedded slates, in Newport, Troy, Coventry, Brownington, Irasburg, Albany, Craftsbury, Greensboro, Hardwick, Woodbury, East Montpelier, Montpelier, Berlin and Northfield. Their line of distribution extends in a north and south direction for about seventy-five miles and in an east and west direction for more than five miles. It is particularly gratifying to have one of the best of these beds located in the Capital of the State.

DRAINAGE.

Only one stream that should be termed a river traverses the area involved in this report. The Winooski River which rises in Walden flows in a southwesterly direction through Marshfield, Plainfield and East Montpelier, in a more westerly direction in Montpelier and from thence in a somewhat northwesterly direction across the axis of the Green Mountains and empties into Lake Champlain. This river receives from the north in East Montpelier Kingsbury Branch which forms the outlet of Woodbury Lake in Woodbury and Calais. Kingsbury Branch receives the waters from Nelson Pond, Mirror Lake, Curtis Pond and numerous smaller ponds. Kingsbury Branch is therefore made up of the confluence of several small streams.

The Winooski River receives from the north in the City of Montpelier Worcester Branch which rises in Elmore and receives small tributaries from the east in Calais and East Montpelier.

The Winooski River receives from the southeast Stevens Branch which rises in Washington. This stream receives from the northeast one tributary which rises in Orange, and from the south a tributary which rises in Williamstown.

The Winooski River receives also from the south Dog River which rises in Roxbury, flows in a northerly direction through Northfield and Berlin and empties into the Winooski at Montpelier Junction. Dog River receives several small streams both from the east and the west. The waters from the extreme western side of Berlin flow into Jones Brook which empties into the Winooski River some two miles below Montpelier Junction. The drainage therefore of the entire area is by the Winooski River and its numerous tributaries.

There are 10 water-powers in Calais. (1) At East Calais on Kingsbury Branch occupied by Dell B. Dwinell and Levison Lamb and Company. (2) At the outlet of Mirror Lake where woolen mills formerly existed but now shingles and slabwood are manufactured by E. A. Dailey. (3) Camerons Falls on the same stream one mile below North Calais, not utilized. (4) At Calais Center on the same stream a small water-power is occupied by D. S. Holt. (5) At Maple Corners on the outlet of Curtis Lake G. E. Mann operates a wood working shop. (6) At Kents Corners J. G. Robinson operates a sawmill. This power is also on the stream that flows from Curtis Lake. (7) There are falls on the same stream a little below Kents Corners but these are not utilized. (8) At Bliss Pond outlet there is a sawmill. (9) On the Dell B. Dwinell Farm a power that is not utilized. (10) At the outlet of Adamant Pond there is a sawmill and wheelwright shop.

On Kingsbury Branch there is an excellent water-power at North Montpelier and another at East Montpelier village both of which are extensively utilized. On the Winooski River there are several power plants for the manufacture of electricity. At the old Pioneer mills about one mile east by southeast of Montpelier there is an excellent water-power now utilized. Another water-power is found on the Winooski River by the Main Street bridge in Montpelier. There is also a water-power in Berlin at Benjamins Falls and in the cascades below them. This power was formerly utilized but it is now idle.

The Central Vermont railroad follows the Winooski River through Montpelier and extends in a southeasterly direction to Barre. From Montpelier Junction the main line runs in a southerly direction through Berlin. The Montpelier and Wells River road which extends from Montpelier to Wells River runs through Montpelier and East Montpelier. At the Barre Transfer a spur extends to Barre. The freight for these two roads is in part farm products, and in part lumber and other manufactured products. The largest single factor in the freight for these roads is the Barre granite for in the township of Barre at Websterville and Graniteville the quarries are reported as the largest monumental granite quarries of the world and the City of Barre as the largest monumental granite center of the world. The output of the rough stone as well as the finished products from the numerous sheds in Barre and Montpelier must pass over one or the other of these two roads.

TOPOGRAPHY.

The area traversed lies practically between parallels 44 degrees and 3 minutes and 44 degrees and 23 minutes north latitude, and longitude 72 degrees 21 minutes and 72 degrees and 40 minutes west of Greenwich. It therefore comprises an area of approximately 125 square miles.

The City of Montpelier which is the Capital of the State lies near the center of the area. It is about 16 miles by the nearest road to the northernmost line traversed and about 7 miles

south of Montpelier to the southernmost line covered this summer. The area is bounded on the north by Woodbury, on the east by Marshfield, Plainfield, Barre and a part of Williamstown, on the south by Northfield and on the west by Moretown, Middlesex and Worcester. It must be remembered that the east and west town lines are not exactly parallel with each other and that they do not all extend in lines north 40 degrees east. They approximate to this direction and to the general strike of the sedimentaries.

The principal valleys are in part longitudinal and in part transverse. The major valley is that of the Winooski River. In the more northern portion of this valley as in Marshfield, Plainfield and East Montpelier the valley is broad, U-shaped and longitudinal. Here it is somewhat parallel with the strike of the limestones over which it flows. In Montpelier the valley becomes a true U-shaped transverse valley for the Winooski River flows directly across the strike of the limestones, slates, schists and quartzites. It is everywhere a broad, fertile valley of pre-glacial origin.

The Winooski Valley is often beautifully terraced. In some instances these terraces will appear on only one side of the river and in others upon both sides of the valley. The present flood plain of the river is extremely fertile and with its associated terraces comprises one of the best farming areas of the central part of the State. How many of the terraces represent ancient lake levels is left for Prof. H. L. Fairchild of Rochester University to say for he has given this problem special attention. Sometimes the terrace material consists almost exclusively of good commercial sand, sometimes of sand and gravel intermixed, sometimes with layers of sand and gravel alternating with each other and sometimes they consist almost exclusively of gravel. Plate A shows a sand and gravel pit on Northfield Street, Montpelier. This sand and gravel is now being used in the construction of permanent roads.

Kingsbury Branch in Calais is terraced. As the altitude of this terrace exceeds 900 feet it is undoubtedly of river origin. A terrace on the west of East Calais has an altitude of 1,100 feet and terrace-like material is occasionally found on the east side of the valley with approximately the same altitude. All of the tributaries that flow into Kingsbury Branch from the west are terraced. Much of this material appears to have been washed out of the terminal moraine of recession that crosses northern Calais and southern Woodbury in an east and west direction.

There are a few terraces in the Dog River Valley. Some of them may belong to Ancient Lake Vermont. About two miles up this valley from Montpelier Junction there is either a peculiarly dissected terrace on the west side of the valley or else the material represents the remnants of a kame. Perhaps the most interesting feature of the terraces in Berlin is found connected with some of the western tributaries of Dog River. On the north side of Stony Brook the terrace has a very pronounced dip to the east thereby implying that this portion of the Green Mountain system has suffered a very recent uplift.

Berlin Pond Valley and the brook which drains the pond is not as well terraced as many other localities. One distinct lake terrace was found with an altitude of 1,100 feet. This is of special interest because it ties up terraces in Calais with the same altitude. The valley itself is 433 feet above Montpelier. It is in part a broad, fertile, U-shaped valley conforming to the general strike of the siliceous limestones over which its waters flow. Near Benjamins Falls the flowage of water is in a more easterly direction. At the Falls it flows directly across the strike of the sedimentaries. The stream descends rapidly by many beautiful cascades from the outlet of Berlin reservoir to the Winooski valley. A part of the way the brook conforms to the beds of limestone over which it flows but most of the way it flows directly across the strike of the limestones and phyllite schists. Plate B shows the cascades near Benjamins Falls, Berlin, Vermont, flowing across the strike of the rocks.

Worcester Branch empties into the Winooski River from the north in the City of Montpelier. The valley is fertile, U-shaped and pre-glacial. The altitude of the valley is low as there are only two falls or water powers in the portion of this valley that properly belongs to this report. One of these is at Jewetts Mills and the other at Wrights Mills. As the terrace material is below the altitude of Lake Vermont the discussion is omitted.

There are numerous transverse valleys in each of the townships covered by this report. They are usually incisional, V-shaped and of post-glacial origin. The Cambrian hills in the western part of each township are especially prone to produce them.

GLACIATION.

The townships traversed for this report are mantled with morainic material to such an extent that the geologist is seriously hampered in his study of the field relations of the different geological formations. This condition holds especially true of the northern part of Calais which is traversed by a terminal moraine of recession, the eastern half of East Montpelier where the glacial till is especially heavy and in the Winooski Valley where lake and river terraces cover the sedimentaries.

Post-glacial transverse valleys have been a prolific source of the desired outcrops. No better illustration of the advantages derived from following up these ravines or valleys can be found

PLATE XL.

CASCADES NEAR BENJAMINS FALLS, BERLIN.
Stream flows across the strike of the schist.

than in the half mile from Benjamins Falls to the Winooski for in this brief distance there are 102 beds of siliceous limestone alternating with as many beds of slate or phyllite schist. The wooded slopes of the Cambrian hills have furnished many rock exposures but the best of all opportunities is afforded by the recently cleared and burned areas and the abandoned slate and granite quarries.

An evidence of glaciation and the general direction of the ice movements is found in the striations still remaining on the more resistant rocks. The limestones and calcareous quartzites have long ago lost their earmarks of glaciation on account of the solubility of their lime content. The outcrops of nearly pure white, secondary, vein quartz still show striations upon their smooth and polished surfaces. The resistant slates and phyllites are the best preservers of this evidence although the Cambrian quartzites often show excellent striations up their exposed surfaces.

Three different directions of ice movement have been recognized in each township. The first direction was south 30 degrees east for this line is cut by the other two. The second movement was generally due south with some local variations for this series of lines is cut only by the series catalogued as the third movement. The third and last ice movement was south 30 degrees west for these lines cut the other two. Perhaps no more interesting locality can be cited than an outcrop some 50 rods north of the old Pioneer Mills on the Winooski River about one mile east by southeast of Montpelier. The striations record all three directions on an outcrop of slate but the peculiar interest attached to them is that one set turns decidedly to the west as they approach the Winooski Valley. Therefore the line of direction is a fairly sharp curve.

Another evidence of glaciation is the boulder strewn fields, pastures and woodlots. The size and angularity of these boulders determine in some measure the distance they have been transported. Their composition sometimes gives both the direction and distance. A large boulder of serpentine was found about one mile west of East Calais that evidently came from the east side of Belvidere Mountain approximately 50 miles to the northwest. (Plate XLI) shows a granite boulder about one mile east of East Calais. From tape measurements and specific gravity its weight is estimated at 175 tons. It evidently was transported by the agency of the glacier from Robeson Mountain in Woodbury. Within a few feet of this boulder there formerly stood a larger boulder whose weight has been estimated to exceed 200 tons. This stone has been quarried and used for underpinnings.

Remnants of a terminal moraine of recession are found in the northern part of Calais and the southern part of Woodbury. The rock material carried by the glacier as medial, lateral, ground moraine and englacial drift was dropped by the ice during its retreat northward where the end of the ice sheet remained stationary for some period of time. This terminal moraine stretches across Vermont in an easterly direction into New Hampshire. In the northern part of Calais and the southern part of Woodbury this material appears as a kettle moraine. The morainic material is here studded with several symmetrical kettle-like depressions, or holes, that at one time were filled with water. A few feet of water was found during the summer of 1916 in the bottom of the kettles. These depressions vary from 50 to 100 feet in diameter and from 25 to 50 feet in depth. The most symmetrical of all of these kettles is situated in a transverse valley about one mile northwest of the village of South Woodbury.

Small drumloid hills are occasionally found in Calais. These are icelaid and furnish additional proof of glaciation. In Berlin on the west side of Dog River Valley there appears an interesting area of kame topography. Fragments of eskers are occasionally found but none of them are as well pronounced as the one in the Eligo Valley in Hardwick. The numerous lakes and ponds in Calais together with Berlin Pond in Berlin are additional proofs of glaciation.

LAKES.

There are 11 lakes and ponds that lie either wholly or in part in the township of Calais. With the exception of Mirror Lake whose origin seems in part to be due to glacial erosion the origin of these lakes is due to glacial filling across pre-glacial valleys. In part they owe their origin to the solution of the limestones which in most cases surround them.

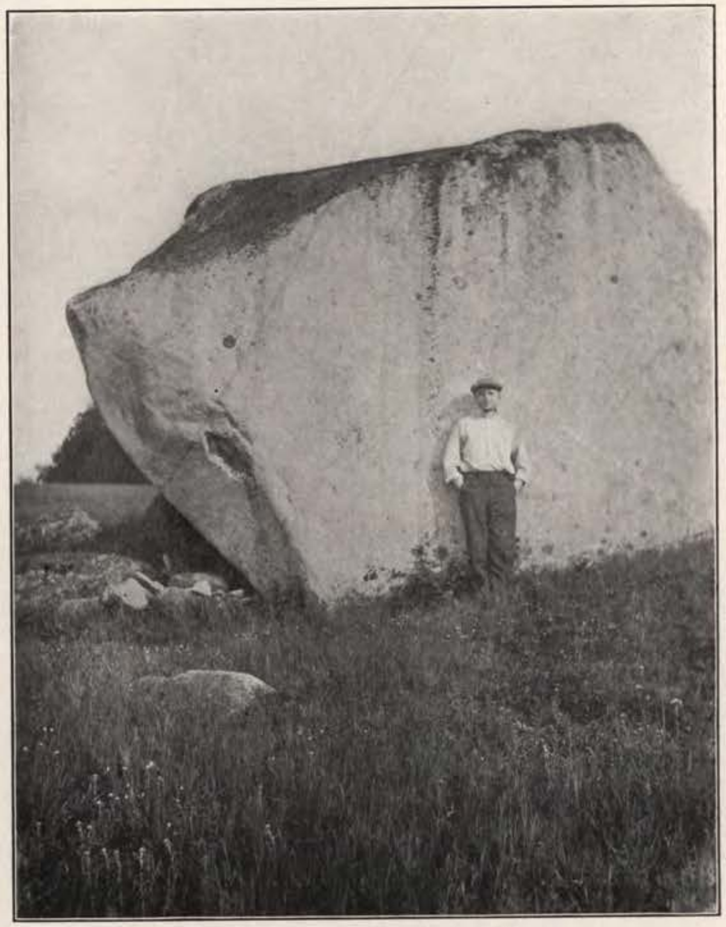
Woodbury Lake is the largest lake of this series. It is situated near the center of the northern part of Calais and west of the road leading to South Woodbury. It lies mostly in the township of Woodbury. It is about 400 rods in length and 200 rods in width. Its acreage is approximately 200 acres. Its outlet is to the south by Kingsbury Branch.

Curtis Pond is situated in the western part of Calais. It is about 350 rods long and 125 rods wide. It contains about 150 acres. Its outlet is to the southeast and flows diagonally across the township into Kingsbury Branch.

Nelson Pond is in the center of the northern part of Calais and lies mostly in the township of Woodbury. Its length is approximately 300 rods and its width 250 rods. It contains about 125 acres. Its outlet is to the south into Mirror Lake.

Mirror Lake is situated about 50 rods south of Nelson Pond and about 100 rods southwest of the home of Col. H. S. Foster. It is 200 rods in length and about 90 in width. It contains about

PLATE XLI.



GRANITE BOULDER EAST OF EAST CALAIS.

85 acres. Its outlet is to south into the brook that flows from Curtis Pond.

The mill pond at North Montpelier lies partly in Calais and partly in the township of East Montpelier. It is some 300 rods in length and 35 rods in width. It contains about 65 acres. Its outlet is by Kingsbury Branch.

Bliss Pond sometimes called Martins Pond is situated in the southwestern part of Calais and south of Blackberry Hill. Its length is about 100 rods and its width about 75 rods. It contains about 40 acres. Its outlet is to the east into the creek that flows from Curtis Pond.

Blue Pond is situated in the northwestern part of Calais. Its length and breadth are each approximately 75 rods and it contains about 25 acres. Its outlet is to the south into the brook that flows from Curtis Pond.

There are two small ponds near Adamant. One is north of the village and the other to the south. They are both well filled with marl. Each of these ponds contains about 25 acres. The outlet of the upper pond is by a small stream that flows south into the lower pond. The outlet of the lower pond is to the south by a small stream that empties into Kingsbury Branch at East Montpelier.

Mud Pond is situated about one mile northwest of East Calais. It contains now about 8 acres. Its sides and the southern end are well filled with marl. The author measured 20 feet depth of marl without striking the bottom of the deposit. There is also a small pond to the north of Maple Corners.

In the township of East Montpelier there is but one pond that has not already been mentioned. It is situated in the northwest corner of the township, and a little to the east of the Horn of the Moon. It is about 65 rods in length and 15 rods in width. It contains about 5 acres. Its outlet is to the west by a small stream that flows into Worcester Branch. The southernmost of the two ponds at Adamant lies mostly in the township of East Montpelier.

In the township of Berlin there is one large pond with the upper and the lower parts connected by narrows. The entire pond known as Berlin Pond is situated a little to the southeast of the center of the township. It is some 2 miles in length and three-fourths of a mile in width at the widest point. It contains nearly one square mile. Considerable interest is attached to this pond for it is the source of the water supply for Montpelier. The outlet is to the northeast by Berlin Pond brook into the Berlin reservoir which is about three miles from Berlin Pond. This reservoir is at Benjamins Falls and is about 25 rods in length and about 10 rods in width. The intake of the city water for Montpelier is situated here. The top of the dam at this reservoir is 364 feet above the Pavilion while Berlin Pond is 438 feet above the Pavilion.

GEOLOGY.

The geology of Calais, East Montpelier, Montpelier and Berlin is intricate and complex. The terranes consist largely of a series of highly crumpled, folded and faulted metamorphic rocks. Almost invariably they dip at a high angle, usually to the west. Occasionally a low dip to the west is observed for a few feet on the eastern side of a small syncline resulting probably from an overturned anticline. This low dip can be seen in the City of Barre about 100 rods west of the post office. It is further located by a cut some 200 feet in length on the Williamstown branch of the Central Vermont railroad. In this short cut there are three synclines with a dip varying from 20 degrees west to 90 degrees. This instance is cited to show the complexity of the problem encountered when constructing a geological section. These metamorphic sedimentaries differ widely in age and in their mineral composition.

These metamorphic sedimentaries have been invaded from time to time by both acid and basic intrusives. The time of the introduction of the acidic granites and pegmatites is regarded as Devonian. The earliest introduction of the more basic dikes into this area was probably at the close of the Cambrian while the latest introduction of this basic material may have been as late as the Triassic. It is the exception rather than the rule that there is only one dike in a given locality. In 1895 the author discovered such a dike at South Barre. No other dike was found within a mile of this dike of cellular basalt. It is best observed between the main road and the railroad as one begins to ascend the hill leading from South Barre to Graniteville. It is not an uncommon thing to find 15 or 20 dikes in a given area within one-half mile of distance across the strike of the sedimentaries. The appearance of a dike cartography on the areal map indicates rather a dike area than the presence of a single dike.

In the further study of the problems more than 100 microscopic slides have been prepared for petrographic identification. The correct definition of the rock often demands this step. The effect of the intrusives upon the walls of the sedimentaries is also desired. The alterations that have taken place in the dikes since their introduction suggest an interesting problem for solution. A microscopic problem is under study concerning the origin of the chlorite schists that often appear as dike-like forms in the Cambrian rocks.

In the western part of the area selected for this report stratigraphy must be determined by field relations for in this area no fossil content has been observed in Vermont. The rocks are

MAP OF MONTPELIER AND EAST MONTPELIER.

so crumpled and closely folded that even then there is a large chance for the introduction of errors.

In the central portion of the field it has been the good fortune of the author to discover 33 different beds of graptolites during the past two summers. This feature will be discussed under the caption of Paleontology. Here lies the true diagnostic feature of age and with the identification of these graptolites by Dr. Ruedemann the age of the limestones, slates and phyllites should be definitely settled.

ALGONKIAN.

There are no rocks that can be recognized as Algonkian in Calais, East Montpelier, Montpelier and Berlin. The introduction of the term is made only to show the relation of the westernmost sedimentaries in the area involved to the Green Mountain gneiss that forms the major axis of the Green Mountains. The Green Mountain gneiss is flanked both upon the east and the west side by a complex series of highly metamorphic and closely folded sedimentary rocks in which no fossil content has been discovered on the eastern side of the Green Mountains. The schists derived directly from the disintegration of the gneiss are feldspathic. In later detailed work it may be possible to establish and separate one schist from another by the presence or absence of a feldspar content. There appears to be no evidence available that the westernmost area covered by this report is as old as the Algonkian.

CAMBRIAN.

The term Cambrian as here used signifies an undivided group of highly metamorphosed sedimentary rocks which lie to the west of the erosional unconformity that separates the pre-Ordovician terranes from the Ordovician. These Cambrian terranes consist of a series of pyritiferous mica schists, sericite schists, chlorite schists, quartzites and slates. This belt in the area covered in this report is the narrowest to the north and gradually widens to the southward until in Berlin it is some two miles in width. This does not imply that the Cambrian belt is any narrower to the north but the west town line of Berlin carries the work further to the west in Cambrian rocks than it does in Calais.

A. SERICITE SCHIST.

The Cambrian area as mapped is undivided because time has been inadequate to prepare and study all of the necessary microscopic slides to establish the mineral composition of each type present. Immediately flanking the Ordovician rocks on the west is a belt of sericite schist. It is usually of fine texture but not always. Its mineralogical composition is quartz, muscovite (sericite), with secondary pyrite and magnetite. In some instances it is quite magnetic. The finely powered schist at Riverton in Berlin responds quickly to the magnet. Many perfect crystals of magnetite can be seen in the outcrop just below the dam near Riverton railway station.

This type of terrane has been continuous from the international boundary on the north for approximately 75 miles in a general direction of south 40 degrees west. In some instances, as at West Albany and in the western part of Woodbury, it is garnetiferous. In North Troy it is as fissile as slate and equally as fine grained.

B. QUARTZITE.

The Cambrian quartzite has been a continuous terrane from the international boundary on the north as far south as Northfield where the work of the present season ceased. It flanks the eastern belt of sericite schist on the west. It varies somewhat in width and is more pronounced in the higher altitudes. It passes by insensible gradations into a sericite schist. Where mica predominates the hand samples are classified as sericite schist. Where the quartz is largely in excess of the mica it is classed as a quartzite. In the higher altitudes in Calais it would extend westward to the west town line. In Berlin it is found as far to the east as the Dog River. Here it appears to underlie the sericite. At least a few feet of the magnetitic sericite schist overlies a quartzite.

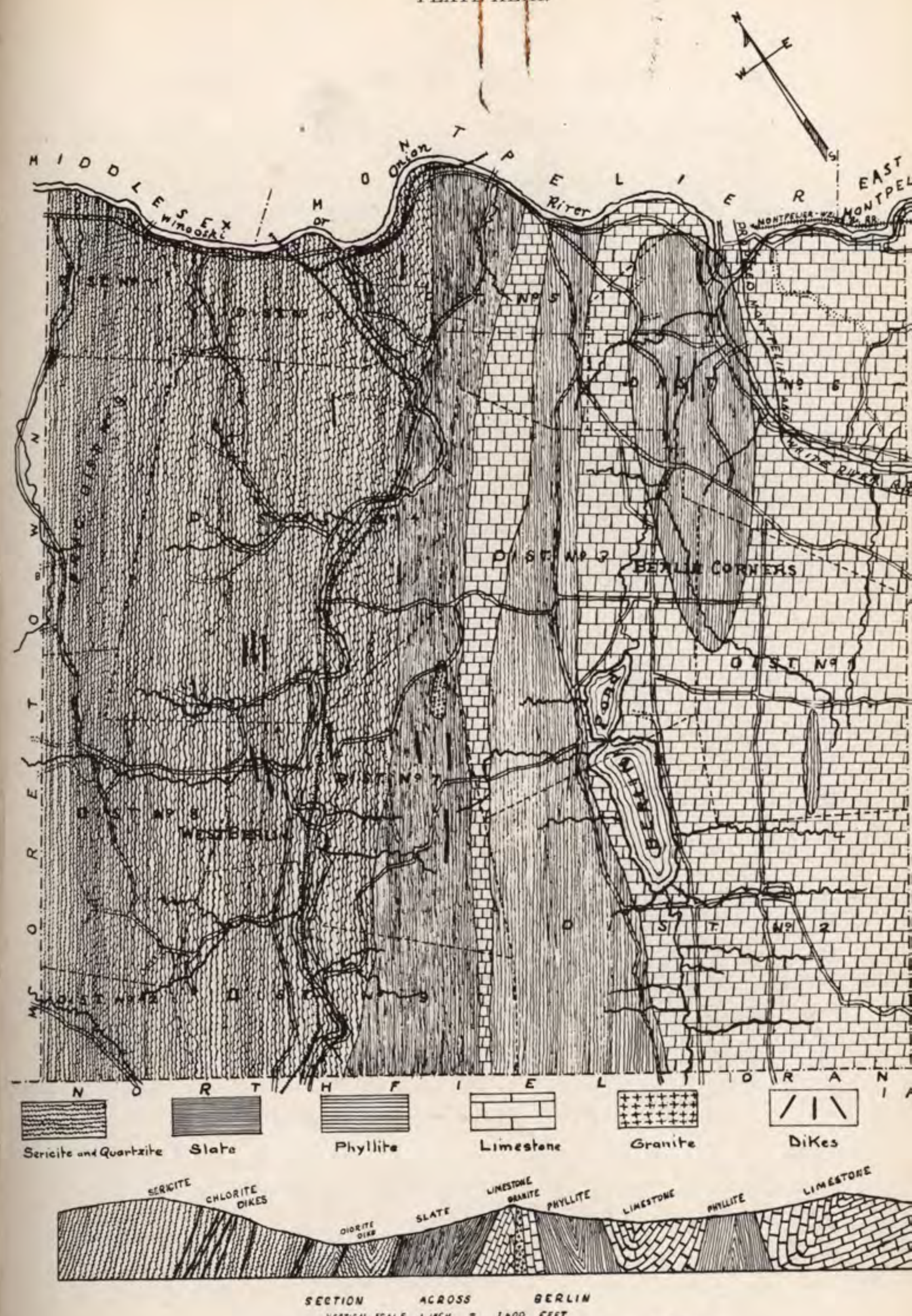
In texture the quartzite is from fine to medium grained but in places it becomes conglomeratic. In mineral composition the quartzite consists of quartz grains, (usually small and well waterworn, but pebbles nearly half an inch in diameter have been found in it), muscovite (sericite), biotite is present in some slides and absent in others. Magnetite is less abundant than it is in the sericite. Pyrites when present are small. Zoisite has been observed.

The author has traversed this formation from Northfield on the south in a northeasterly direction for more than 100 miles. It has taken him into Canadian territory where Upper Cambrian fossils have been found. In the entire distance the formation has not lost its lithological characteristics. It is for this reason that the quartzite and the schists into which it passes by insensible gradations are classified as Cambrian.

PYRITIFEROUS MICA SCHIST.

The pyritiferous mica schist that was so pronounced in Troy, Westfield and Lowell should appear in Middlesex, Moretown and the western part of Northfield. It is possible that the sericite schist that flanks the quartzite on the west in all the townships covered by this report is a part of this schist formation.

The typical pyritiferous mica schist is characterized by an abundance of quartz and black, or greenish black, hydrated mica



MAP OF BERLIN. Scale 400 rods = 1 inch.

in which large crystals of pyrite occur. This greenish black hydrated mica may have been derived from biotite. In the more northern locality the schist at the surface is marked by many large cavities formed by the oxidation of the pyrite crystals, and the leaching out of the secondary minerals formed during this oxidation.

D. SLATE.

There are no merchantable slates of Cambrian age in the area covered by this report. The rock that has sometimes been locally classified as a slate is in reality a fine grained sericite schist with the fissility of slate. This slaty belt which in the western part of Woodbury near Slayton Pond is garnetiferous extends southward into the western part of Calais. The typical slaty texture was not observed in East Montpelier, Montpelier and Berlin.

E. CHLORITE SCHISTS.

The chlorite schists appear as thin beds varying from a few inches to 50 feet or more in width in the Cambrian terranes. In many cases they are parallel with the sericite schists and quartzites of unquestioned sedimentary origin. In some instances the schists that are pronouncedly chloritic traverse the sedimentaries as if they were derived from dikes. Some of the microscopic slides already prepared and studied strikingly suggest an igneous origin at least for some of the schists. If the chlorite was derived from the biotite in a sedimentary rock there should remain free quartz in the chlorite schist. The augite of a diabase dike may alter to hornblende and the hornblende may become chlorite. Many samples from these chloritic rocks were collected this summer for microscopic slides in the hopes that petrographic study would throw some light on the problem.

The general strike of the Cambrian terranes in Calais, East Montpelier, Montpelier and Berlin is north 40 degrees east. In the belt as a whole there are many variations which are more or less local. In Montpelier near the contact of the Cambrian and Ordovician terranes the strike was recorded as north 50 degrees east. On the hills to the west of Worcester Branch the strike was north 50 degrees east while in Middlesex the strike was found north 30 degrees east. This does not mean near Middlesex village but on the hills south of Shady Hill in the township of Middlesex. On the back side of Long Meadow Hill in Calais the strike was north 70 degrees east. On Woodbury Mountain in Woodbury an east and west strike was recorded. The strike sometimes changes very abruptly. It sometimes changes either towards the east or the west 10 degrees within 2 feet.

On the eastern side of the Cambrian terranes the general dip is about 70 degrees to the west. There are instances where this dip on the east is as low as 60 degrees and others where it is as high as 80 degrees to the west, while in Hardwick and Woodbury there is an easterly dip near the contact with the Ordovician terranes. As a rule the dip becomes higher as one traverses the Cambrian rocks toward the west until it reaches the vertical then decreases to 70 or 80 degrees west. The eastern leg of another anticline is encountered only a little to the west of the west town lines as covered in this report. In general there are two synclinal troughs and one anticlinal axis mapped in this western area. (Plate XLIV) shows the sericite schist with westerly dip near the railroad tracks in Berlin, Vt. This view is in the eastern syncline. (Plate XLV) shows the banded Cambrian quartzite near Green Mountain Cemetery, Montpelier, Vt.

ORDOVICIAN.

The term Ordovician as here used embraces a group of metamorphic sedimentaries that lie to the east of the Cambrian terranes already described. The line of contact in Calais passes over Hersey Hill and Long Meadow Hill. In East Montpelier the contact is about half way between the west north road to Calais and the east turn north in the Horn of the Moon loop. The Horn of the Moon Mountain is in the Cambrian. In Montpelier the contact is about one mile up Worcester Branch. The line extends southward over Capital Hill. It extends down into the Winooski Valley a few rods east of the State House and crosses the Winooski River about midway between the Taylor Street bridge and the railroad bridge a few rods west of the Vermont Central station. In the Dog River valley in Berlin the contact is near the railroad. About two miles south of Montpelier Junction the line passes to the west of the railroad tracks for a short distance only. The rest of the way the contact is east of the railroad. The Falls at Northfield Falls are in the Ordovician.

The erosional unconformity which was discovered in Irasburg has been followed northward into Canada and southward into Northfield. In this conglomerate a pebble of Cambrian quartzite more than six inches in diameter was found this summer at Northfield Falls. The distance north and south this conglomerate has now been followed is more than 75 miles. The Ordovician terranes consist of a basal conglomerate, limestones, marble, calcareous quartzites, phyllite schists, and slates. No sedimentary rocks younger than the Ordovician are found in this area. At the close of the Ordovician a crustal movement accompanied with elevation and complex folding took place which drove the Ordovician sea out of Vermont to the northward into the St. Lawrence valley and metamorphosed the Ordovician sediments into limestones, marbles, quartzites, slates and schists.

PLATE XLIV.

SERICITE SCHIST NEAR RAILROAD, BERLIN, DIPS WESTERLY.

A. IRASBURG CONGLOMERATE.

The author discovered this formation near the village of Irasburg in 1904. In it there are pebbles of diabase, granite, porphyrite, quartzite, sericite schist and a sericitic marble. These pebbles are all pre-Ordovician. The matrix is limestone and Ordovician. Metadiabases and metadiorites appear in the Cambrian terranes of northern Vermont. Some of these have been so sheared that they present a decidedly schistose appearance. There are also several granite areas in the Cambrian terranes in which the granite has in part been sheared into gneiss while the granite center is more or less porphyritic. Some of the Cambrian granite bears well defined crystals of purple fluorite while the greasy appearance of the granite is suggestive of a syenite. Several microscopic slides of this granite show its mineral composition to consist of quartz, orthoclase, biotite and fluorite. This definition has also been given this intrusive by the Canadian Geological Survey. This granite is quite unlike any Devonian granite in eastern Vermont.

It has been conjectured by some geologists in private correspondence with the author that the granite pebbles in the conglomerate are Devonian. A Devonian granite can not appear as pebbles or boulders in a conglomerate that lies at the base of the Ordovician. That pre-Ordovician granites were introduced into pre-Ordovician sedimentaries in northern Vermont is apparent to anyone who who will make a careful study of these intrusives both in the field and in the laboratory.

The general strike of this conglomerate has been north 40 degrees east but the strike sometimes changes 90 degrees within 10 feet. It has been powerfully folded into sharp anticlines and synclines and these folds dip in all possible directions. Its general dip has been to the west but in Hardwick in the Eligo valley it dips to the east.

The distance to which this conglomerate has been carried is significant. It has been proven to extend in a northeasterly and southwesterly direction for more than 100 miles. Its presence as far south as Northfield where the quartzite boulder more than six inches in length was found in it this summer is interesting and suggestive of a much larger distribution than was at first supposed. How much farther to the southward this conglomerate can be found is only a matter of conjecture.

B. WAITS RIVER LIMESTONE.

The Waits River limestone is the largest single geological formation in the area covered by this report. The proportionate area however is not as great as it is in Hardwick and Woodbury for the sericite schists swing further to the east and the phyllite schists are more abundant. The formation includes several beds of quartzose marble, some calcareous quartzite and many beds of phyllite schist that are not mapable areas but everywhere interstratified with the limestone. Where these calcareous sediments appear to predominate the area is mapped as limestone. Where the non-calcareous sediments predominate the area has been mapped either as slate or phyllite schist according to the amount of secondary cleavage that has been introduced and the amount of metamorphism the beds have undergone. Perhaps some geologists would have mapped the entire area as schists and quartzites.

The Washington phase of this limestone which is dark steel gray and compact is perhaps the most abundant. It contains several beds of quartzose marble which are susceptible of a good polish. One of these beds is at the cascades in the village of East Calais. This is perhaps the best exposure in the township of Calais. A badly shattered marble bed is found near the village of Calais. Some two miles south of this village there is a considerable area of the dark colored quartzose marble.

In the eastern half of East Montpelier the limestones are dark gray and compact. In fact they are essentially quartzose marbles. The same condition holds true of the eastern part of Berlin. Such a bed can be seen near the crest of the hill some two miles east of Berlin Pond. The large and productive farms to the northeast of Berlin Corners owe their productivity in part to the decomposition of this belt of quartzose marble.

The Waits River phase which is banded, variegated or even of a light gray color can be seen about one-half mile east of East Calais. It appears to be the most abundant where erosion has been the least pronounced. The eastern part of the townships have all carried beds of limestone that belong to this phase. Perhaps the thin bedded and shaly limestones that are largely interstratified with the slates and schists are the Waits River phase. In the more northern areas this thin bedded and shaly material is more banded by the alternation of light and dark gray layers than it is in the more southern portions. The shaly nature has predominated in the more western limestones all of the way southward from the international boundary on the north.

The bed of calcareous quartzite in the southeastern part of Woodbury extends southward into Calais, or at least appears in Calais. As the quartz is in excess of the lime content or rather the calcium carbonate content the rock is cataloged as a calcareous quartzite. The rock is simply a more highly siliceous phase of the Waits River limestone and not a separate geological formation distinct in characteristics from the terranes on its east and west sides.

The more massive portions of the limestones are susceptible of a good polish and are best cataloged as quartzose marbles. They weather on long exposure to the corroding agents of the atmosphere a rusty brown. They are best suited for decorative

PLATE XLV.

BANDED CAMBRIAN QUARTZITE NEAR GREEN MOUNTAIN CEMETERY, MONTPELIER.

interior work, although some of them are usable along monumental lines.

Microscopic slides of these marbles show well developed crystals of calcite with perfect cleavage. The sand grains which constitute about 25 to 30 per cent. of the rock mass are small and well rounded. Three micas have been observed; muscovite, the white mica; biotite, the black mica; phlogopite, the amber mica. Microscopic, and sometimes macroscopic, pyrite is present in a part of the limestone or marble. Uncombined carbon serves as a pigment. These scattered massive beds may be regarded as marble reserves.

The more siliceous portions of the marble often weathers with peculiar forms. These seem to resemble various animals and birds and are often placed in dooryards for decoration. (Plate XLVI) shows a peculiar solution cavity in the massive limestone on the farm of George Balentine in the northern part of Calais, Vt.

The beds of limestone are more shaly and friable in the western part of the limestone area than in the eastern part. Not only are the individual layers themselves thinner in the western part but the beds as a whole are thinner. Therefore in the eastern part where the more massive beds appear and the limestone predominates over the schists the area is mapped in as limestone. In the western part of the limestone area where the non-calcareous sediments predominate over the calcareous the area is mapped as slate or phyllite schist according to the character of the cleavage and the amount of metamorphism the rock has suffered.

The interbedding of the limestone members with the schists can be seen perhaps at the best advantage along the bed of the stream that flows from the Berlin reservoir into the Winooski valley. In a distance of one-half mile there are 102 beds of limestone with as many beds of schist. The calcareous beds will vary in thickness from a few inches to 50 feet. On Seminary Hill in the City of Montpelier, some 50 rods south of the Seminary there are 10 beds of limestone interstratified with as many beds of slate within a distance of 50 feet. Plate J shows the limestone overlaid with phyllite schist one mile northwest of East Calais, Vt.

The normal strike of the limestones and marbles in the area covered by this report is north 40 degrees east and the normal dip is to the west. Plate K shows an outcrop of graptolitic limestone a few rods east of the Catholic cemetery, Montpelier, Vermont, showing westerly dip.

The strike however is subject to many local variations. In the southern part of Berlin around Berlin Mountain a north and south strike was recorded. Also a strike nearly east and west. In the northen part of Calais in several localities the strike is north 70 degrees east. In Woodbury the strike sometimes is east and west. In the area involved in this report the strike seems to vary from north and south to east and west. The east and west strikes are due to more intense folding and crumpling of the rocks.

The dip is subject to the many variations. The lowest dips encountered are near the eastern town lines. In Barre a dip as low as 15 degrees is recorded. This dip is on the eastern side of a syncline, and within 25 feet of this low dip a dip of 90 degrees has been recorded. In many of the small synclines a low dip is characteristic of the eastern side and a dip of 90 degrees or nearly 90 on the west. The dip of the whole synclinorium being practically to the west.

In the central portions of these townships the dip is generally from 75 to 80 degrees to the west. Near Clay Hill in Montpelier the dip is from 85 degrees west to 90 degrees west. At Benjamins Falls the dips are 85 degrees west, 90 and 85 degrees east. Just below these falls is a most excellent illustration of the intense folding which this area has undergone. In this gorge the closely folded anticlines and synclines are easily seen and very pronounced.

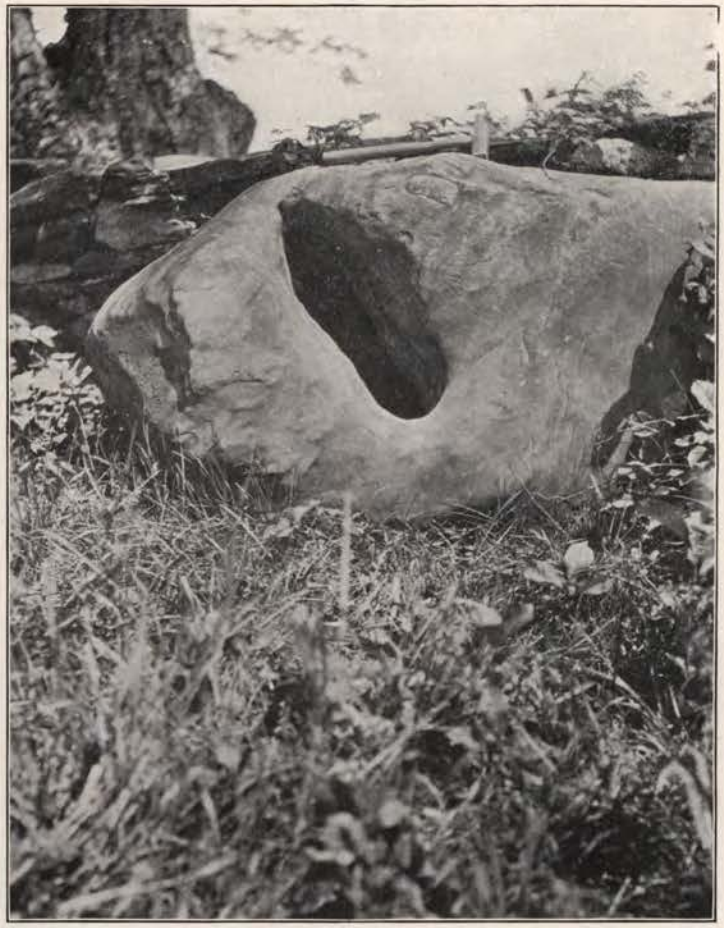
On the west side of Berlin Mountain and near its summit there are seven crests of anticlines in the slate belt within a distance of 50 rods. An effort will be made to photograph these rock exposures next summer and describe the structure in connection with the report covering Paine Mountain in Northfield.

C. PHYLLITE SCHIST.

The eastern belt of the non-calcareous sediments of Ordovician age is in part responsible for the higher altitudes on the eastern border of the townships covered by this report. The belt appears in the higher altitudes of eastern Calais and western Marshfield. In its southern extension it passes into Plainfield. There are some of these schists interstratified with the limestones in East Montpelier. A narrow belt of schist near the southeastern part of Berlin belongs in this field. With the absence of a lime content this schist has more stoutly resisted both solution and erosion than the adjacent limestones and marbles. It must be remembered however that the compact quartzose marble on the eastern side of this area is a fairly resistant rock to decomposition by atmospheric agencies. This illustration can be seen in the higher altitudes about two miles southeast of Berlin Pond.

The schists vary from fine to medium in texture save where they come in contact with either acid or basic intrusives when they become sometimes fairly coarse grained. Mineralogically considered they are biotite-muscovite-quartz schists. They are often spangled with lenticular plates of ottrelite set transverse to the planes of foliation. Where metamorphism has been the

PLATE XLVI.



SOLUTION CAVITY IN LIMESTONE.

greatest these spangles are the largest and most abundant. They vary in size from 0.1 millimeter to 1 millimeter. They bear both pyrite and magnetite. Magnetite sometimes forms the nucleus of the ottrelite spangles. Macroscopic pyrite is fairly common. Where these larger crystals or lenses of pyrite are absent microscopic pyrite will appear in the thin sections. Garnets are common also in the more highly metamorphic portions of the outcrops. Acicular crystals of secondary hornblende are common near the contact of these schists with intrusives. Occasionally near the granite intrusions epidote is present.

An excellent illustration of this garnetiferous phase is found in the eastern part of Calais and the western part of Marshfield. The strike is north 40 degrees east and the dip 75 degrees west. About one-fourth mile east of the house of George Balentine in the northern part of Calais the garnetiferous phyllite schist is highly graphitic. Here the strike is north 58 degrees east and the dip 40 degrees west.

The central belt of phyllite schist appears to the west of the village of East Calais. A small area is found near the outlet of Nelson Pond which lies partly in Calais and partly in Woodbury. Another area appears in the southern part of Calais about one-half mile west of the main road leading from North Montpelier to East Calais. The strike of this belt varies north and south to north 8 degrees east and the dip is 60 degrees west.

The continuation of this belt through East Montpelier is rendered somewhat uncertain by the abundance of glacial drift. It is certain that the belt extends into the northern part of East Montpelier. It appears again within the limits of the city of Montpelier and embraces the schists and limestones in the Benjamins Falls area. Here the calcareous and non-calcareous members comprise a closely folded series of anticlines and synclines. The belt appears again on the west side of the road leading from Berlin Reservoir to Berlin Corners. In its more southern extension it is lensed out by the limestones. Many of these non-calcareous beds appear as lens shaped areas in the limestones and marbles. Perhaps some would say that limestones and marbles form the lens shaped masses rather than the schist, but the calcareous sediments are in excess of the non-calcareous sediments in the areas just described.

This entire central belt in its northern extension in Newport and Coventry forms a part of the Memphremagog slate. South of Coventry it has been metamorphosed into a schist and it is only here and there that local beds have a slaty cleavage and the true slate ring.

D. SLATE.

The western member of the Memphremagog slates as described in the previous reports has not been continuous from the

garnet

phyllite in Montpe[lier]

international boundary on the north as given in the Vermont report of 1861 by Edward Hitchcock and others. The belt was broken in Craftsbury because erosion was carried below the level of the lower beds of slate. In Hardwick the slate belt again disappears. It reappears in Woodbury and forms a continuous belt southward into Northfield as far as my work has been extended.

In the extreme northern part of Calais the slate belt is quite narrow. It increases in width until it becomes approximately one mile wide in the central and southern part of Calais. This width is roughly maintained through East Montpelier, Montpelier and Berlin. The slate belt in Montpelier will extend in a somewhat easterly direction from a few rods east of the State House to the old Pioneer Mills on the Winooski River. There are some narrow beds of limestone interbedded with the slate. One of these calcareous beds can be seen in the long rock exposure on Northfield Street on the Berlin side of Montpelier. Another belt lies to the west of the old Sabin slate quarry east of Seminary Hill. These calcareous beds appear to the southward in Berlin. It appears to the northward in the northern part of East Montpelier.

The slates vary from bluish-gray to black in color. They are fairly fissile and trim easily to specimens 3 by 4 inches. They possess the characteristic slaty ring and are sufficiently strong to permit being nailed to a roof without splitting. They are carbonaceous and magnetitic. Pyrites are usually visible on the sawn edges and grains of pyrite are sometimes seen in the microscopic slides. A few garnets are present in the more highly metamorphosed portions of the slate belt. A few small staurolites have been observed. The slate in the more western portion of the belt does not effervesce in cold dilute HCl but in the more eastern portion of the belt where the beds are more interstratified with the limestone there is some effervescence.

There is an abandoned quarry of slate about one mile from Montpelier on the road to Adamant. There is a second abandoned quarry, known as the Cutler quarry just beyond Cutler cemetery on the road to North Montpelier. The third abandoned quarry is situated near the south end of Taylor Street bridge and is known as the Langdon quarry. The fourth abandoned quarry is situated across the valley east of Seminary Hill and is known as the Sabin slate quarry. Plate L shows the Sabin slate quarry, Montpelier, Vermont. The view is taken looking out of the quarry and shows the different sets of joint planes.

The general strike of the slate in this belt has been north 40 degrees east. On Berlin Mountain a north and south strike was recorded. On the Berlin side of Montpelier the strike was north 30 degrees east. In East Montpelier the strike was north 40 degrees east. In the northwestern part of Calais a strike of north 50 degrees east was observed and on Woodbury Mountain there is an east and west strike. The trend of the formation as

PLATE XLVII.

LIMESTONE OVERLAID WITH PHYLLITE.

a whole is approximately north 40 degrees east. The general dip is to west. It varies from 60 degrees west to 90.

In the History of Vermont by D. P. Thompson, 1860, there is a bit of history that throws some light on the character of this slate belt with its interstratified limestones. The author of this report begs leave to quote the data here. According to the late John H. Senter the location where the following bit of work was done is about 100 feet west of the Wells River depot in Montpelier. The work appears to have been executed by Patrick Fenley between Aug. 8, 1827 and Jan. 4, 1830. The effort was to drill a well to 2,100 feet in depth for the purpose of obtaining salt. At a depth of 850 feet I understand that the drill broke and the work was discontinued.

"The rock formation for the first 70 feet, hard or soft slate running into impure lime with an occasional seam of white flint or quartz. From 70 to 80 feet, 10 feet of sandstone. From 80 to 121 feet soft slate. From 121 to 131 feet sandstone. From 100 to 200 feet alternating layers of slate and lime with two layers of sandstone. From 200 feet to 300 feet almost wholly blue lime. From 300 to 303 feet flint and lime intermingled. From 303 to 308 feet white sandstone. From 308 down to 850 feet alternating layers of lime and slate, the slate soon running into lime and the lime more and more predominating, with no other rock through the whole distance to change the formation.

"At a depth of 400 feet we think the drill suddenly broke into a cavity of the depth of 5 or 6 inches and a copious stream of water gushed out; not pure water; it appears of a salty or corrupting quality similar to specimens impregnated with bog ore and rotten wood. We boiled down a few quarts of it to half a gill, but with no other result than to show that it contained no salts of any kind which could be detected by evaporation.

"The dirt and rubbish lying over the mouth of this perforation was last summer removed by the direction of James R. Langdon, about 200 feet of the old shafting of the well drawn out and a lead pipe inserted from which may now be seen running the same old spring in a volume about an inch in diameter which would probably be twice as large but for the obstruction of the shaft still remaining wedged in below.

"Such is the history of the attempt of boring for salt at Montpelier, which has often been lightly treated by the unreflecting, but which has been regarded by the reflecting and scientific with much interest, and with a disposition to honor the chief projector (Daniel Baldwin) and his associates in a laudable undertaking for it has given them a correct knowledge of the rock formations to a great depth of this central part of Vermont, which otherwise had never been obtained. And as to the main object, it is by no means a settled thing, that, had the intended or a greater depth been attained, salt water could not have been found.

The formation was becoming, at the lower portions of the perforation, one of continuous hard limestone, which is known to be full of cavities and often of very extensive fissures through which the salt water, even admitting no salt to be indigenous to the locality, might have found its way from its great central fountains in western New York."

To the author of this report there is considerable interest attached to the above report. It substantiates many statements appearing in previous reports. It proves the interstratification of the slates and limestones in this western slate belt and indicates the same interstratification for the more eastern belts. The 10 feet of sandstone recorded as appearing twice can be the same bed of calcareous quartzite reappearing in a close fold. In some of the cuts this close folding has been observed. It must be remembered that the dip is here at a high angle to the west and therefore the beds of sandstone cited would not be 10 feet in thickness. The hard and compact limestone comprising nearly all of the formation from the 308-foot depth to 850-foot depth would probably be the Washington phase of the Waits River limestone. This information is important because the author has always advocated that the slates of this western belt were the youngest of the Ordovician sediments in the eastern half of Vermont. It furthermore explains why the limestones appear flanking the Cambrian schists where erosion has been carried sufficiently low to remove the slate.

ACID INTRUSIVES.

GRANITES.

The uplift that occurred at the close of the Ordovician caused sedimentation to cease in the eastern part of Vermont and atmospheric erosion to begin. At the close of the Devonian another crustal movement occurred which was accompanied by the intrusion into the sericite schists, quartzites, phyllite schists, limestones, marbles and slates, granitic material in a state of fusion with superheated water. These intrusions induced further changes in many of the sedimentaries and in places injected them with dikes of pegmatite. Acicular crystals of hornblende appear in the phyllite schists, limestones and marbles as products of contact metamorphism. Epidote is occasionally found in the limestones and marbles. Zoisite has been found in the marbles of Ordovician age and the sericite schists and quartzites of Cambrian age.

Soon after the crystallization of the granites they were traversed by dikes of pegmatite and aplite. The granites of the main granite belt of Vermont and the Province of Quebec have long been recognized by both American and Canadian geologists as of Devonian age. While the main belt lies to the east of the

PLATE XLVIII.

GRAPTOLITIC LIMESTONE, MONTPELIER.

townships covered in this report there is no reason to believe that the granite outliers of this report are of other than Devonian age.

CALAIS.

The largest granite area in the portion of Vermont covered by this report lies in the southwestern part of Calais and within one mile of the village of Adamant which was formerly known as Sodom. The granite belt approximates one mile in length and 100 rods in width. The strike of the belt is approximately north 30 degrees east and the granite quarries lie along the southeast side of the granite ridge. The granites are marked by the absence of sheet structure and the occurrence of graphite in connection with the quartz veins. Plate M shows the granite quarry of Patch and Company, Adamant.

According to T. Nelson Dale this granite is a biotite granite of medium, slightly bluish gray color, and of even grained medium texture, with feldspars up to 0.3 inch, rarely 0.4 inch, and mica up to 0.1 inch. The larger feldspars are crystallized about the quartz and mica and give the stone something of a porphyritic texture. Its constituents, in descending order of abundance, are: Clear colorless potash feldspar (orthoclase), somewhat kaolinized and micacized, with microcline, with inclusions of the other constituents; clear, colorless quartz with but few cavities; bluish to milk-white soda-lime feldspar (ologoclase-albite more or less altered); biotite (black mica); and a little muscovite or bleached biotite. The accessory minerals are apatite and zircon. The secondary minerals are kaolin, calcite and a white mica. This granite effervesces slightly with cold dilute HCl.

This granite is of the same shade as medium Barre but of less bluish and more greenish tinge. Its mineral contrasts are stronger and its texture a little coarser. Its large clear feldspar crystals give brilliancy to its rough surface.

The typical sheeted structure of the Barre and Woodbury quarries is here absent. One set of joint planes strikes north 85 degrees east and dips 50 degrees to the south. These joints are spaced from 2 to 15 feet apart and are slickensided in a southwest direction. The face of the slickensided surface is graphitic. The second set of joints strike north 85 degrees east and dip from 40 degrees north to 90 degrees. These joints are spaced from 20 to 75 feet and in places are discontinuous. The rift is north 30 degrees east with a dip of 50 degrees north 60 degrees west. The grain is reported to strike north 85 degrees east and to dip 50 degrees to the south. The product from this quarry is used for monumental work and finds its chief market in the middle west.

The quarry of the Lake Shore Quarry Company, Montpelier, was idle this summer. The stone is a biotite granite which is a little darker in color than the light Barre and a little lighter than the medium Barre. Its shade corresponds to that of the well known granite of Hallowell, Maine. The output of the quarry has been used for both monumental and constructional work. The Soldiers' Memorial Building in Stowe, Vt., represents this stone.

The old quarry reported to be that of the Eureka Granite Company of Montpelier was also idle. The quarry opening is about 350 feet by 80 feet with a working face on the north 105 feet high.

An abandoned quarry was also found on the northwest shore of Bliss Pond. No large amount of granite has here been quarried. The stone is suitable for monumental work.

About one-half mile east of the farm of F. M. Corliss, there is an outcrop of granite which is 100 rods in length and some 30 rods in width. It is a biotite granite with good rift and grain and has been worked somewhat for underpinnings. The locality is some 2 miles north of Adamant and the cost of haulage has been so great that the stone appears to have never been quarried for monumental purposes.

East Montpelier.

In East Montpelier there is but one granite area that warrants mapping in as other than a dike. This outcrop is found in the northwestern part of the township on the east side of the road leading from Montpelier to Adamant. It is about 100 rods in length and some 30 rods in width. No abandoned openings were found although there are some evidences of good granite possibilities.

Berlin.

In the township of Berlin there is one mapable granite area which is situated about one mile east of the village of West Berlin on the right of the road leading from West Berlin to Berlin Pond. The granite area is approximately 2,500 feet in length and 500 feet in width. At one of the quarry openings the major joints had a strike of north 40 degrees east with a less prominent set of joints with strike north 50 degrees west. The strike of the rift appeared to be nearly north and south. In this area there are several abandoned quarries and none are being worked at the present time.

GRANITE MANUFACTURERS.

A list of the granite manufacturers or producers in Calais together with the abandoned quarries is given below.

Patch and Company of Adamant are now working from 10 or 12 men. The stone is monumental.

PLATE XLIX.

SABIN SLATE QUARRY, MONTPELIER.

The abandoned quarries around Adamant in Calais are, viz.:

The Paul Terreo Quarry.

The Joe Barney Quarry.

The Lake Shore Granite Company's Quarry.

The Lynch and McMahon Quarry.

The Eureka Granite Company's Quarry.

The Newell Wright Quarry.

The Martin Quarries.

The D. L. Fuller Quarries.

There were formerly granite sheds at East Montpelier but these have been abandoned.

The list of the granite manufacturers in the city of Montpelier in operation since June 1st, 1916 is given below.

The Poulin Granite Company, J. Poulin, proprietor, employs 8 men. The work is monumental and the stock is Barre.

The Artistic Granite Company, Simeon Garand, proprietor, employs 8 men. The work is monumental and the stock is Barre.

Robert M. Fraser employs 20 men. The work is monumental and the stock is Barre.

In the sheds of R. M. Fraser, R. L. McGovern employs 4 men. The work is monumental and the stock is Barre.

In the Fraser sheds also G. Ariole and Company employs 3 men. The work is monumental and the stock is Barre.

The Johnson Granite Company employs 10 men. The work is monumental and the stock is in part Barre, Vt., and in part Quincy, Mass.

The E. Roy Granite Company employs 10 men. The work is monumental and the stock is Barre.

The Capitol Granite Company, A. B. Staples and David Anderson, employ 28 men. The work is monumental and the stock is Barre. They also wholesale granite from Ryegate, Vt., and Quincy, Mass.

Robert Lawrence employs 20 men. The work is monumental and the stock is Barre.

In the Lawrence sheds there are 4 small firms whose work is all monumental and whose stock is Barre. They are as follows:

Maloney and Clossey employ 4 men.

Caron Brothers employ 3 men.

Garand and Forque employ 4 men.

Anderson and Rooney employ 3 men.

The G. R. Bianchi Granite Company employs 50 men. The work is monumental and the stock is Barre.

The Juras Granite Company employs 20 men. The work is monumental and the stock is Barre.

In these sheds there are 2 small firms whose work is monumental and whose stock is Barre.

R. A. LeClerc employs 8 men.

Pilini Granite Company employs 7 men.

The Green Mountain Company, L. N. Wood, owner, employs 15 men. The work is monumental and the stock is in part Barre and in part the S. Berwick, Maine, granite. Mr. Wood controls the sale of the Green Mountain Granite for a considerable territory.

In the sheds of Mr. Wood there are 3 small companies whose work is monumental and whose stock is Barre.

Flannery and Caslani employ 5 men.

E. Fernandez employs 5 men.

E. Canas employs 5 men.

The Excelsior Granite Company employs 50 men. The work is monumental and the stock is Barre.

The National Granite Company employs 30 men. The work is monumental and the stock is in part Barre and in part Adamant.

In the same sheds Oldson and Nelson employ 4 men. The work is monumental and the stock is Barre.

The U. Aja Granite Company employs 12 men. The work is monumental and the stock is Barre.

Under these sheds there are 2 small companies whose work is monumental and whose stock is Barre.

R. Sierra Granite Company employs 3 men.

Gomez and Company employ 2 men.

The Sheridan and Poole Company employs 10 men. The work is monumental and the stock is Barre.

Under these sheds there are 4 smaller companies whose work is all monumental and whose stock is Barre.

Valley and Beaudette employ 6 men.

H. C. Emerson employs 2 men.

Frazier and Lavisque employ 5 men.

George Servright employs 3 men.

Mills and Company employ 10 men. The work is monumental and the stock is Barre.

C. P. Gill and Company employ 24 men. The work is monumental and the stock is both the light and dark Barre.

In these sheds there are 3 small firms whose work is monumental and whose stock is Barre.

E. Lachapelle Granite Company employs 4 men.

Pando Granite Company employs 5 men.

Vermont Granite Company employs 2 men.

The Columbian Granite Company under the management of T. E. Callahan employs 20 men. The work is monumental and the stock is Barre.

The Doucette Brothers, Alfred and Frank, employ 28 men. The work is monumental and the stock is Barre.

Bonazzi and Bonazzi, E. Bonazzi, proprietor, employ 30 men. The work is monumental and the stock is Barre.

Beaudette and Doucette employ 10 men. The work is monumental and the stock is Barre.

PLATE L.

PATCH AND COMPANY'S GRANITE QUARRY, ADAMANT.

In these sheds there are 2 small firms whose work is monumental and whose stock is Barre.

Menard and Erno employ 3 men.

Pama Granite Company employs 4 men.

At West Berlin, or Riverton as the railway station is now called, there are 2 firms manufacturing monumental work from Barre granite.

The Davis Brothers employ 50 men and Provost and Son employ 25 men.

ACID DIKES.

In the western part of Calais and to the north of the road to Worcester there is a granite dike about 15 feet in width. The strike of this dike is north 40 degrees east. It cuts Ordovician slates.

About one mile west of Maple Corners there is a brownish granite dike about 1 foot in width. The strike is north 40 degrees east. The brown color is due to the oxidation of the iron content in the dike.

About one mile to the southeast of Kents Corners there is a granitic dike several rods in width. Its strike is north 30 degrees east.

Some 50 rods east of Bliss Pond near the three corners of the road there are 2 granitic dikes. One is to the east of the intersecting roads and the other is to the west. The easternmost dike is 12 feet in width and crosses the road. The westernmost of these two dikes is 3 feet wide. Their strike is north 30 degrees east.

A long dike of more than 2 miles length and apparently some 4 or 5 miles in length appears in its more northern extension about 100 rods to the west of Bliss Pond. It parallels the road from Bliss Pond to Curtis Pond. It is about 5 feet in width, strike north 40 degrees east. It appears to be aplitic, of a rusty brown color and badly decomposed. The dike is known to extend southward into the township of East Montpelier and similar material appeared as a dike in this township more than 2 miles south of the north town line. It has the same strike north 40 degrees east and is apparently a continuation southward of the same dike.

In the southwestern corner of Calais about one mile west of Adamant there are 3 dikes of granitic nature. They range from 4 to 7 feet in width and strike north 30 degrees east.

To the east of Blackberry Hill and almost northeast from Adamant there is a series of granitic and aplitic dikes of unknown number, they vary in width from 1 to 25 feet. The wider dikes are granitic. Their strike approximates north 30 degrees east.

In the township of East Montpelier near the northwest corner there are 10 closely bunched granitic dikes. They vary in width from 3 feet to about 300 feet. Their strike varies from north 30 degrees east to north 40 degrees east and cut slate whose strike is north 50 degrees east.

Along the high ridge east of the turn to the Horn of the Moon there is a long aplitic dike about 20 feet wide whose strike is north 30 degrees east.

On the east of the road extending north from the Morse schoolhouse in connection with a mass of granite already described there are several pegmatitic dikes whose strike approximates north 30 degrees east.

A little to the west of the Morse schoolhouse there are 2 aplitic dikes. One is 10 feet in width and the other about 6 inches. Their strike is north 35 degrees east.

In the township of Berlin there are several granitic dikes that extend southward from near the main granite mass on the road from West Berlin to Berlin Corners. Several of these dikes can be seen in the pasture on the west side of what is known as the Taylor road leading to the top of Berlin Mountain. They appear upon both the east and the west slopes of this pasture hill.

Another granitic dike extends southward for a considerable distance on the west slope of Berlin Mountain. Another dike is found about 100 rods to the east of the main granite mass. It is about 5 feet in width. Another dike can be seen to the west of the granite mass and is about 10 feet in width. The granite mass itself which is about 2,500 feet in length and 500 feet in width may be a large dike.

BASIC DIKES.

In the township of Calais on the road from Maple Corners to Worcester there is an hornblendic dike with strike about north 30 degrees east.

On Hersey Hill and Longmeadow Hill in the southwestern corner of Calais there are 2 hornblendic dikes with strike north 30 degrees east. They are each about 3 feet in width.

On the road to Worcester about 75 rods west of these two dikes there are 2 hornblendic dikes near the western town line. One of these may be in the township of Worcester. Their strike is about north 30 degrees east and the width about 2 feet.

In East Montpelier in the north loop of the Horn of the Moon there are 3 dikes. The one that crosses the road is an altered diabase. The two to the north of the road are more or less hornblendic.

In Montpelier to the west of Worcester Branch either true dikes or dike-like material was encountered in 57 different places. The first line was run to the west a little to the north of Green Mountain Cemetery. This line encountered 13 dikes. The second line was run to the west some 2 miles and started just north of Capital Hill. It encountered 16 dikes. The third section was run to westward for about 2 miles. The line is about one mile north of Montpelier. Its eastern end terminates at Worcester Branch. It encountered 11 dikes. The fourth section was extended westward from Worcester Branch about 2 miles. The line is about 2 miles north of Montpelier. It encountered 17 dikes.

Some of these dikes may be duplicates but there can not be less than 17 as that number was encountered in the northernmost section. As 16 dikes were encountered on the second section then these 16 dikes must be over 2 miles in length if they are duplicated in the section 2 miles to the north which has the 17 dikes. These dikes vary in width from 1 foot up to 15 feet. The general strike of the easternmost dikes is north 50 degrees east and of the westernmost dikes north 20 degrees east. In many cases the strike conforms with that of the enclosing sedimentaries. In some cases these dikes cut the strike of the sedimentaries at an angle as high as 20 degrees. Such dike-like masses are unquestionably of igneous origin. It is not yet proven that some of the apparent dike-like material whose strike is parallel with the enclosing rocks of undoubted sedimentary origin are not themselves highly altered sediments. Chips for the preparation of microscopic slides have been collected from many of these dikes to aid in settling the question of their origin.

Their composition as far as could be determined in the field suggests the following types: diabase, diorite, porphyritic diorite and chlorite schist. The chlorite schists that appear as dikes are the ones that may have been of sedimentary origin. Yet the microscopic study of the slides already prepared from some of these point to an igneous origin.

In the township of Berlin about 1 mile south of Montpelier Junction on the road to West Berlin and on the Lathrop farm there is a highly altered diabase dike whose strike is north 35 degrees east and whose dip is 80 degrees to the west. The width is approximately 5 feet. On the range of the Cambrian hills between this point and the Winooski River there are several dike-like masses some of which are unquestionably dikes. As many of these are in the line of the strike of dikes already cited in Montpelier to the north of the Winooski River these dikes were not counted. One of the chlorite schist masses that appears dike-like in character can be seen under the railroad bridge near the Central Vermont railroad station and on the Berlin side of the river. The spotted sericite schist whose hand samples suggest an igneous origin may be an altered diabase dike. The dark spots are mica of dark green color, which may have been the original augite of a diabase.

A chlorite dike appears in the gorge 50 rods west of the river road at West Berlin. The strike is north 40 east and the dip 85 to 90 degrees west.

Two chlorite dikes appear in the bed of the Dog River at West Berlin. Their strike varies from north and south to north 50 degrees east. They vary from 1 to 3. feet in width.

In the Stony Brook valley to the west of the road leading from Montpelier Junction to West Berlin there are 2 dikes which are chloritic. Their strike is north 40 degrees east. They vary from 2 to 6 feet in width.

Along the first road west of the road leading northward from West Berlin there are 5 chloritic dikes within 500 feet of each other. Their strike is north 40 degrees east and their width varies from 1 to 10 feet. Their dip varies from 85 degrees west to 85 degrees east.

A cross section was run from the Dog River valley directly westward and a little north of the old Montpelier Poor Farm in Berlin to the crest of the western range of hills in Berlin. This section encountered 77 dike-like masses of which 71 were chloritic, 3 feldspathic with well defined crystals of feldspar standing out prominently on the weathered face and 3 diabase dikes. The general strike is north 40 degrees east but some of them appear to cut across the strike of the sedimentaries which encircles them. It is not to be understood that all of these chlorite rock masses here cited represent actual dikes of igneous origin. During the coming winter many microscopic slides will be prepared for petrographic study of this material.

About 10 rods north of the railroad bridge near West Berlin there is a dike of porphyritic diorite. Its strike is north 40 degrees east and the dip is about 75 degrees to the west.

A little to the southwest of West Berlin on the road leading to Northfield there is a dike of amygdaloidal basalt cutting the Cambrian terranes. The dike is about 2 feet in width. Its presence here is significant because this is the first instance in which the author has found a dike of amygdaloidal basalt cutting rocks of Cambrian age. They are not infrequent in the terranes of Ordovician age.

Two additional dikes of amygdaloidal basalt observed this summer may be cited here although strictly speaking they do not belong to this report. They are however in a contiguous area. One of these is in the Jones Brothers quarry near Websterville in the township of Barre. Its strike is north 70 degrees east traversing the sedimentaries whose strike is north 40 degrees east. The dike is about 3 feet in width. The other dike is in the City of Barre at the foot of the hill and between the railroad tracks and the main road leading to Graniteville. The dike shows many fine samples of spheroidal weathering. The dike is about 4 feet in width and strikes nearly east and west.

In the gorge leading from the Barre road up to Benjamins Falls there are 2 dikes of camptonite about 50 rods apart. One strikes north 22 degrees east and the other north 50 degrees east. The former is 6 feet in width and the latter is 2 feet in width. These dikes contain many phenocrysts of hornblende.

The granites of the area covered by this report have long been regarded as having been introduced into the sedimentaries at the close of the Devonian. There is evidence in their mineralogical composition, in their microscopic structure and in their quarry structures that they have been subjected to a pronounced crustal movement. Such a folding accompanied by uplift came at the close of the Carboniferous age.

Not long after the crystallization of the granites they were traversed by granitic dikes (pegmatite and aplite). The acid dikes are regarded as having been introduced at this time. The basic dikes which are definitely known to be younger than the granites, for they often cut the granites, are regarded as having been introduced as late as the Carboniferous and possibly as late as the Triassic. It is not certain that all of the basic dikes cutting the Ordovician terranes were introduced at the same time. Some of them have suffered decomposition until their presence is suggested by a moat or ditch, which upon excavation is found to contain a basaltic dike with marked spheroidal weathering. Excavations have been made in some of these dikes to a depth of 25 feet and still the spheroidal weathering is very pronounced. These masses quickly fall apart into a coarse sand or gravel.

Dikes like the camptonite near Craftsbury Common and elsewhere sometimes stand out prominently like a stone wall and show a rind of only a small fraction of an inch. The phenocrysts of hornblende appear perfectly fresh upon the broken faces of the rock. The small amount of decomposition or alteration these dikes have undergone suggest a later age than the Carboniferous.

The basic dikes with the exception of the amygdaloidal basalt near West Berlin, cutting the Cambrian terranes are certainly much older than the dikes cutting the Ordovician terranes and are regarded as having been introduced at the close of the Cambrian.

PALEONTOLOGY.

The erosional unconformity that exists between the Cambrian and Ordovician terranes was discovered by the author of this report in Irasburg, Vermont, in 1904. This true basal conglomerate which reveals the existence of an erosional unconformity was then named by the author the Irasburg Conglomerate. This conglomerate has been traversed northward into Canada and to the southward through Irasburg, Albany, Craftsbury, Greensboro, Hardwick, Woodbury, Calais, East Montpelier, Montpelier, Berlin and into Northfield. This distance is approximately 100 miles. In Northfield this summer the author found pebbles of Cambrian quartzite more than 6 inches in length in this conglomerate. In the entire distance the pebbles have been of Cambrian material and the matrix Ordovician. In the more northern portion the matrix is lime and in Northfield it is essentially slate. This conglomerate lies at the base of the Ordovician series of sedimentaries in eastern Vermont and is brought into view only where erosion has been carried downward nearly to the bottom of the Ordovician beds. In some instances the conglomerate has been entirely removed and its characteristic intense crumpling is seen in the exposed Cambrian terranes. Such an instance can be found in the Lamoille valley in Hardwick.

The sericite schists, sericitic slates, sericitic quartz schists, quartzites and sericitic marbles cataloged as Cambrian all lie to the west of this unconformity, and to the east of the Green Mountain axis. They are regarded as Cambrian because they have been traversed to the northward with the same lithological characteristics into Canada where Upper Cambrian fossils have been obtained.

The black or bluish black slates and their associated shales were named by the author of this report the Memphremagog slates. This name was suggestive because these slates in their northern extension in Vermont dip under Lake Memphremagog and appear on the eastern side of the lake where graptolites have been found in them. This name is retained for the slates and shales in their southern extension as far southward as the work of the author has been carried which is approximately 100 miles.

It has been the belief of the author ever since he found the graptolites in Canada in the slates and limestones of Ordovician age that graptolites would be found in the eastern part of Vermont sufficiently well preserved to identify with certainty the age of the slates, phyllite schists, siliceous limestones and quartzose marbles in eastern Vermont.

Graptolitic beds have now been found by the author, in either the calcareous or non-calcareous sedimentaries, and in some townships in both, in Newport, Coventry, Brownington, Irasburg, Albany, Craftsbury, Greensboro, Hardwick, Woodbury, Calais, East Montpelier, Montpelier, Berlin, Northfield and Barre. The last named locality was found in September, 1916, in the City of Barre. This discovery of a few graptolites 6 miles east of the easternmost Cambrian terranes is significant. The bed in Brownington is about 5 miles east of the graptolitic limestone in Coventry. Beds of graptolites have not only been found near the western border of the Ordovician rocks but in the eastern part of all townships covered by this and the preceding reports by the author covering the area southward from Lake Memphremagog. It is reasonably certain that graptolitic remains can be found in the next

tier of townships to the east because of the lithological similarity of the rocks and because graptolites have been found in this line in both Barre and Brownington. In each of the last 10 years of work in Vermont the author of this report has found new graptolitic beds, but it is of especial interest that during the last two summers and in the area covered by this report 33 different beds have been discovered. In some of these beds the graphitic forms present are as numerous as the graptolites are in the classic area at Castle Brook, Magog, Quebec. The rocks in Vermont are more highly metamorphosed than they are in Canada in the graptolitic areas and therefore the forms of these diagnostic features are not as perfectly preserved.

The space is inadequate in this brief report for the citation of all of the 33 beds of graptolites discovered during the last two summers. The better localities only will be located.

In the township of Woodbury the most productive locality is situated on the eastern side of Valley Lake, which was formerly known as Dog Pond, and to the south of the bay known as Hart's Tongue. They appear in both the calcareous and non-calcareous sedimentaries. The crushed graptolites are more numerous here than at any other locality thus far discovered in eastern Vermont. In fact hundreds of specimens can be obtained on a single hand sample.

In the township of Calais the most productive locality discovered is to the west and south of Blackberry Hill. This area is also to the west of the Adamant granite. The graptolites are here in the thin bedded siliceous limestones and the forms are fairly abundant. Three distinct beds about 100 rods apart were here discovered.

In the township of East Montpelier the most productive locality is situated in the northwestern part of the township and a little north of the road that leads to Adamant from the west hill road that runs north through the township of East Montpelier. This bed is within 2 rods of the main road that extends north into Calais and Woodbury. The face of an abandoned quarry where only a little stone has been removed for underpinnings or culverts is thickly studded with graphitic patches which parallel the schistosity of the thin bed of calcareous quartzite.

The City of Montpelier has been a prolific territory in the author's quest for graptolites. The best locality is located near the entrance to the Catholic cemetery on Clay Hill. It is about 100 feet east of the road that leads from the Clay Hill road to the Catholic cemetery. The author expects next summer to make an excavation in the soil west of the outcrop of the thin bedded siliceous limestone and with drills and wedges obtain some fine specimens for the State museum at Montpelier. This work is especially desirable because here this summer graptolites were obtained that suggest the Deepkill division of the Ordovician for the extremely thin bedded and shaly limestones, sometimes calcareous quartzites, that are intimately interbedded with the Memphremagog slates.

It is with peculiar interest that the author records the finding of graptolites in the disused Sabin slate quarry just east of Seminary Hill. A few specimens have been found in the slate but the most of them were discovered in the beds of quartzose marble on the left of the entrance to the last chamber, and therefore the third, from which the slate was quarried between 1884 and 1887.

T. Nelson Dale of the United States Geological Survey visited this locality to obtain data for his work on "Slate in the United States," issued as Bulletin 586 in 1914. On page 120 of this publication Dale says "Conclusive paleontological evidence on the subject is yet lacking." Graptolites from this bed have been definitely recognized by Dr. Ruedemann as Climacograptus pavus of Ordovician age.

In Berlin-Montpelier only a few rods west of the entrance to Dewey Park in the limestone beds interstratified with the phyllite schist the author found this summer some well preserved forms some of which were sent to Dr. Ruedemann the same day that they were collected. Under date of June 22, 1916, Dr. Ruedemann writes "The specimen which you sent me is quite distinctly a small Climacograptus. It shows still the characteristic outlines of the cells and the nemacaulus, also the original shape of the distal end."

Many graptolites were also found in the thin beds of siliceous limestone, all mapped in as slate because the slate predominates in Berlin-Montpelier some 10 rods to the west of the steep hill road just east of Northfield St.

In the township of Berlin the best locality is situated on the north slope of Berlin Mountain near the crest of the pasture hill some 50 rods south of the road that leads from Berlin Pond to West Berlin. A thin slab, some 12 inches in linear dimensions, from this locality has been placed in the State Museum at Montpelier.

In the township of Northfield graptolitic beds in shaly limestone and associated slates were found on the southwest side of Berlin Mountain, a little to the north of Paine Mountain in Northfield.

From the foregoing data it appears that graptolitic material is most abundant in a rather narrow belt of extremely thin bedded limestone, often quite shaly, and always interstratified with slate, that stretches from Lake Memphremagog southward into Northfield. How much farther to the southward this belt can be traced is a matter of conjecture, probably at least as far south as Barnard for here the slates appear less metamorphosed than they are in the more northern area. It must not be forgotten however that the width of the belt in which the graptolites have already been found is at least 6 miles.

In an earlier report concerning graptolitic material sent from Craftsbury Dr. Ruedemann wrote, "These suggest Phyllograptus and Diplograptus." In a letter of September 26, 1914, concerning graptolitic material from Greensboro and Woodbury, Dr. Ruedemann wrote "These are quite certainly graptolites, probably branches of Dichrograptus and Didymograptus." In a letter of September 20, 1916, concerning new material from the localities cited in this report, Dr. Ruedemann wrote, "Graptolites with double series of thecae (Climacograptus or Diplograptus)." May be the last Deepkill zone or Normanskill shale (Ordovician, about Chazy age). This material was the pyritic shale from Valley Lake, Woodbury, Vermont.

Concerning the material in the shaly limestones from East Montpelier he wrote, "The elliptical patches might be specimens of Phyllograptus, indicating Deepkill shale (Beekmantown)." Concerning new material from the Sabin slate quarry he wrote, "May be worm tubes or branches of dichograptid graptolites." Concerning the graptolitic material from the shaly thin bedded limestone near the Catholic cemetery, Montpelier, he wrote, "Apparently a Tetragraptus, comparable to Tetragraptus amii, or serra, in size and outline. This would make it Deepkill shale (Lower Beekmantown). There occur also shaly limestones in our Deepkill graptolite shales."

In a letter of August 8, 1916, Dr. Ruedemann wrote, "The most remarkable graptolite is undoubtedly a Tetragraptus amii and proves the presence of the Deepkill (Beekmantown) shales. It is quite significant that it occurs in a shaly limestone, since the Deepkill graptolite beds differ from the others in being intercalated with thin limestone beds. If this is a Tetragraptus then the broad blotches are quite probably Phyllograptus, as the Deepkill zones are well developed in your metamorphic rocks. Also the long straight graptolites look more like forms of the Deepkill than of the Normanskill zones."

As the Canadian limestones and slates bearing Lower Trenton graptolites pass under Lake Memphremagog and appear again in Newport and Coventry it would suggest that the range of age for these limestones and slates in eastern Vermont was from the Deepkill to the Lower Trenton. In any event they are Ordovician where the author placed them in 1895. He has never contended that they were all Lower Trenton, but rather has advocated that deposition began fairly early in Ordovician time and ceased with the Lower Trenton. Paleontological evidence now supports this view.

ECONOMICS.

The sericite schists and quartzites of Cambrian age in the western part of the area covered by this report appear to be of little, if any, commercial value. Slabs have occasionally been split out for underpinnings and bridge or culvert construction. These sedimentaries are frequently traversed by veins of secondary quartz bearing traces of gold but nowhere in the area involved is the gold found in commercial quantities. Reports of the panning of placer gold in the narrow valleys amongst these western hills are not uncommon, but no one was found who had ever panned the gold, nor were there any evidences discovered of the existence of such placers.

Although the Memphremagog slates are often pyritiferous they are in some instances quite fissile. It is possible that in the western part of Calais that beds of slate can be found that would make a fair roofing slate for local consumption. The same condition holds true for the slate belt as it traverses East Montpelier in its southern extension. Here and there small openings are found that indicate an attempt at some time to use this material.

The best deposit of slate in Montpelier is located a little to the east of Seminary Hill. It is known as the Sabin slate quarry which was being worked about 30 years ago. The quarry was operated by 3 wide openings across the strike of the slate which is about north 20 degrees east with a dip of 75 degrees to the west. The large openings communicated with each other by an open cut through which the slate could be transported to the splitting sheds over temporary rails. This cut also served as a drain for the quarry. Between 1880 and 1887 this quarry was in active operation and the slate manufactured at a mill that stood near the quarry opening. The quarry is said by some to have been abandoned on account of the large percentage of waste. This waste resulted from the complex method of opening the quarry and the way in which the slate was quarried. By others the quarry is said to have been abandoned as a result of financial mismanagement.

There is however at this disused quarry a considerable amount of good slate within one-half mile of the Central Vermont and the Montpelier and Wells River railroads. The vein of secondary quartz that exists upon the quarry floor and a little above it should not discourage capital from opening the quarry. There is a bed of very good slate not 30 feet back of the present working face.

The slate itself is almost black, perhaps a very dark gray color with a smooth, lustrous cleavage face. This slate is very fissile and sonorous. It does not discolor and therefore it belongs to the unfading series of slates. This slate should find a ready market for roofing purposes and mill stock.

Slate was formerly quarried for roofing purposes in two places near the Cutler cemetery. One of these was known as the Cutler slate quarry. Both are now disused save as a little material is quarried from time to time for cellar walls or road material. The Langdon quarry was opened on the Berlin side of Taylor Street Bridge. The material was quarried for roofing purposes but the quarry was long ago abandoned.

Slate outcrops suitable for roofing purposes and mill stock have been reported to exist in several places in Berlin. The most promising of these are on the west side of Berlin Mountain but they are too inaccessible to be of much commercial value. Erosion has been carried far lower in Montpelier than it has in either Calais or Berlin and therefore the slates in Montpelier are far superior to those in Calais and Berlin.

The phyllite schists as a rule do not present commercial propositions. In Calais on the farm of F. M. Corliss, about one-half mile south of Kents Corners and about two and one-half miles north of Adamant there is a whetstone bed of some commercial significance. The rift and grain of the stone is so perfect that good whetstones with almost perfect form can be easily trimmed out with a small geological hammer and chisel. These stones possess a good grit and do not gum upon continued use. One of these whetstones trimmed out in June this year was used during the haying season in Washington, Vermont, this summer, and when seen in September it had worn as well as the best whetstones from the Pike Manufacturing Company in Haverhill, New Hampshire.

This whetstone belt extends south 40 degrees west for about 2 miles and passes under a part of Bliss, or Martins Pond. Around this pond many fine whetstones have been obtained for local use. The dip of the whetstone schist is 60 degrees to the west.

In the southeastern part of Calais and about one mile west of Kingsbury Branch and on the farm of Walter Chapin there occurs a bed of whetstone schist which has a strike of north 40 degrees east and a dip of 45 degrees to the west. The strike of the phyllite a few rods to the east of this belt is north and south and the whetstone schist appears as a lens shaped mass in the phyllite schist. The rock is however a lenticular bed of calcareous quartzite. The stone has a good rift and grain. The grit is sharp and good serviceable whetstones can be manufactured from this material.

The limestones and quartzose marbles have been used locally in the construction of permanent roads, in abutments and guards of bridges, in culverts, in foundations for houses and barns. These limestones possess good rift and grain and work easily into regular rectangular blocks. The beds of quartzose marble are susceptible of a high polish and when freshly cut the contrast between the hammered and polished surface is quite strong. One of these beds of marble is found at East Calais at the foot of the falls on Kingsbury Branch. A bed of this quartzose marble is also found near the central part of Calais and another bed in the southern part of the same township.

A massive marble bed more than 50 rods in length and several rods in width appears in the township of Berlin about 2 miles east of Berlin Pond. It is an excellent stone for underpinnings but no attempt has been made to use this material as a marble. In fact nearly all of the limestone area of the eastern part of Berlin has been somewhat calcitized.

In nearly every township in this section of the State the limestones have been burned at some time in the manufacture of lime. The lime is reported to have been slightly bluish white or grayish in color and very durable. The plaster in many of the houses in this section of the State is reported to have been made from lime from these local kilns and sand from the local stream banks. One of these old kilns which was in use about 75 years ago was found on the farm of Thomas McKnight in Calais.

The granite industry in this area is of quite limited extent. The only actually producing granite company this summer is Patch and Company of Adamant in the southwestern part of Calais. This company employs 12 men. The stock is good for monumental work and the output should be much larger than it is at the present time. As cited earlier in this report there are 9 or more abandoned quarries around or near Adamant. Cost of transportation by haulage with teams some 10 miles to Montpelier has been a determining factor in this industry.

Several quarry openings some of them of considerable dimensions were found in the township of Berlin about one mile east of West Berlin on the road to Berlin Pond. This granite is reported to have worked easily, to have good rift and grain and the quarries to have been abandoned on account of the difficulties encountered in hauling the stone down the steep grade into West Berlin, the nearest point for shipping the stone.

The basic dikes encountered in the western half of all of these townships would make an excellent road metal but they are generally of too limited extent to be of commercial significance.

The clay banks flanking the numerous small streams in this area have furnished the material for the manufacture of brick for building purposes. Building brick were burned on the farm of Alvin Cameron about 75 years ago and from these brick Nelson Chase and Perry Marsh constructed the two brick houses now found on the road from Pekin to North Calais. These houses are now owned by Eli A. Houghton and testify as to the beauty and durability of the brick.

Another house built of brick manufactured in Calais is found in the northern part of the township. This brick house although manufactured from brick in 1816 is still well preserved. The lime for the mortar in which the brick were laid was burned from marl from the marl beds around a small pond about one mile south of the house.

In Montpelier the clay beds that lie between the Sabin slate quarry and Seminary Hill have been used in the manufacture of brick. There are clay beds still remaining from which good brick can be manufactured.

The marl beds as noted in a preceding paragraph may be utilized in the manufacture of lime. But of greater significance is the possibility of these marl deposits as fertilizers. One of the largest of these deposits is situated on the farm of E. W. Cate near North Calais. At the outlet of a small pond the author tested the depth of the marl this summer and found 20 feet of marl without reaching the bottom. The marl deposit is several rods in width and with varying depth extends southward from the pond for about 100 rods.

C. H. Jones, Chemist for the Burlington Agricultural Experiment Station in a letter of March 2, 1914, wrote to Mr. Cate "The insoluble matter in your marl is 9.65%, lime 47.90%. The amount of lime is equivalent to 85.50% $CaCO^3$. If you can easily get at this deposit it should prove of value towards supplying your lime need."

Peat and muck deposits of large distribution and unknown depth are fairly numerous in the vicinity of the smaller ponds in Calais. A considerable amount of this material is also found on the east side of the lower pond at Berlin Pond in Berlin. Much of this material could be easily removed and used directly as a fertilizer.

Under date of March 2, 1914, C. H. Jones wrote Mr. Cate of North Calais concerning the composition of the muck deposits "Nitrogen 2.06%, ash 33.98%, insoluble matter 27.20%. While the insoluble matter is rather high, yet the material would rank as medium grade as judged by its nitrogen content."

REPORT

OF THE

STATE GEOLOGIST

ON THE

MINERAL INDUSTRIES AND GEOLOGY

OF

VERMONT

1915-1916

TENTH OF THIS SERIES

GEORGE H. PERKINS

State Geologist and Professor of Geology
University of Vermont

BURLINGTON, VT.
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TABLE OF CONTENTS.

LIST OF PLATES.

FIGURES IN THE TEXT.

LIST OF ALTITUDES IN VERMONT.

By G. H. Perkins.

The following List of Altitudes in Vermont has been compiled from many sources and though not complete, it does include by far the greater part of the State.

There are a few localities in the State that have never been studied and no elevations either by leveling or aneroid have been obtained. When the Topographical Survey of the State, now in progress, is finished it will then be possible to give the height above sea level of all places and not till then.

At present rather more than half of our total area has been surveyed in such a manner that contour lines can be given and what has been done is largely on the western side of Vermont.

This is mainly because in the progress of the New York Survey in cooperation with the U. S. Geological Survey the quadrangles as they were mapped extended eastward across Lake Champlain and included a portion of the Vermont side of the Champlain Valley. When later the U. S. Survey undertook work wholly in Vermont, they had no cooperation on the part of the State and carried on their work as seemed best to them.

In 1913 the State for the first time contributed to this work and for the first time was entitled to advise as to localities to be surveyed and for the most part it was considered better to continue the work directly from those areas already surveyed rather than to do a little here and a little there in different parts of the State. If the Legislative appropriation does not fail, the entire State will in time be surveyed.

It is scarcely necessary to say that wherever they were available the U. S. Topographic maps have been used in preparing this list.

The value of these maps for many purposes has been mentioned in previous Reports. Rather more than half the State has thus far been mapped.

Single maps or any number of copies can be obtained from the following:

Bennington, E. T. Griswold; Brattleboro, Clapp and Jones; Burlington, Custom House, L. W. Fennell; Chester, National

Survey Company; Rutland, The Tuttle Company; Woodstock, W. H. Moore.

The maps for all parts of the Country may be bought from the Director, U. S. Geological Survey, Washington, D. C.

In small number the maps cost ten cents each, but fifty may be had for three dollars and these may be all alike or all different or in any order the purchaser wishes.

By application to the Director at Washington a key map which shows just what topographic maps have been put on sale, will be sent without charge.

Most useful in ascertaining altitudes is Bulletin 274 U. S. Geological Survey, *A Dictionary of Altitudes in the United States* and this publication has been constantly used in compiling the following list. However, since the publication of the above Dictionary several quadrangles have been surveyed and there are many localities unmentioned in this Bulletin, especially in the northern and eastern parts of the State. Where these authorities cannot be used whatever list was obtainable has been consulted and aneroid measurements have been taken where possible. The lists given in Beers Atlas of Vermont, published in 1893 and the figures given by Professor Guyot in American Journal of Science, vol. XXX, 2nd series, page 157, have been used in default of any later figures.

Through the courtesy of the engineers of the several railroads running across Vermont and of various city engineers many elevations have been obtained that otherwise could not have been given in this list. Aid has also been received from Professors J. W. Votey, P. N. Swett and A. E. Winslow of the Engineering Departments of University of Vermont, Middlebury and Northfield as to localities determined by their classes. Aneroid determinations have been used only when these were the only measurements that could be had.

While all due care has been taken to secure accuracy in the aneroid measurements, and when possible the observations of two persons were taken or several observations on different days, it should be understood that all such altitudes are provisional and to be considered as no more than approximate, nearly approximate it is hoped, but not exact. Probably the aneroid measurements for the most part do not vary more than a very few feet from what could be found in leveling. In the smaller towns usually only a single elevation is given, but in large towns and especially those built on different levels, several figures are given showing the height of different parts of the town. When possible an altitude is located in front of the main hotel, schoolhouse, town hall or church so that it may be readily found.

There are numerous hills and mountains in different parts of the State with altitudes of 100 to over 2,000 feet, the heights of which have been accurately determined, but which cannot be listed because they have never been named and therefore cannot be designated.

The following abbreviations are used:—

A. J. C. .... A. J. Crosby, Supt. Springfield Railway.
Aneroid .... Altitudes taken by Aneroid Barometer when no others were to be had.
B. A. R. .... B. A. Robinson, Engineer, Bellows Falls.
Beers .... Beers Map of Vermont.
B. and M. R. R. .... Engineers of Boston & Maine Railroad.
C. P. R. R. .... Engineers of Canadian Pacific Railroad.
C. V. R. R. .... Engineers of Central Vermont Railroad.
G. A. R. .... G. A. Reed, City Engineer, Montpelier.
F. O. L. .... F. O. Lee, City Engineer, Barre.
H. L. F. .... Professor H. L. Fairchild, Aneroid.
M. C. R. R. .... Engineers, Maine Central Railroad.
M. and W. R. R. R. ..... Engineers, Montpelier & Wells River Railroad.
R. Aneroid .... Professor C. H. Richardson.
Rut. R. R. .... Engineers, Rutland Railroad.
St. J. and L. C. R. R. ... Engineers, St. Johnsbury & Lake Champlain Railroad.
U. S. G. S. .... United States Topographical Survey.
U. S. C. & G. S. .... United States Coast and Geodetic Survey.
U. Vt. E. .... University of Vermont Engineers.
White .... Altitudes in Canada, James White, Ottawa, 1915.

It has seemed best that all Vermont localities, at any rate all places having a Post Office, should be named even though no elevation can be given for, as the Survey of the State progresses, these will be determined and can then be added.

ELEVATIONS IN VERMONT.

Locality.	Authority.	Elevation. Feet.
Ackworth, Bristol	U. S. G. S.	630
Adam Pond, Jamaica	U. S. G. S.	960
Adamant		Unknown
Addison	U. S. G. S.	280
Albany		Unknown
Alburg, R. R. Station	U. S. G. S.	127
Alburg, Greenwood School	U. S. G. S.	150
Alburg Center	U. S. G. S.	140
Alburg Springs	U. S. G. S.	131
Aldis Hill, St. Albans	U. S. G. S.	840
Alfrecha	U. S. G. S.	553
Algiers, Guilford	U. S. G. S.	440
Allens Pond, Marlboro		Unknown
Ames Hill, Marlboro	U. S. G. S.	1,862
Amsden		Unknown
Andover		Unknown
Anthony, Mount, Bennington	U. S. G. S.	2,345
Antone, Mount, Rupert	U. S. G. S.	2,660
Arlington	U. S. G. S	691
Arrowhead Mountain, Milton	U. S. G. S.	947
Ascutney Mountain	F. P. Gulliver	3,114
Ascutney Mountain	A. D. Hagar	3,326
Ascutneyville, Weathersfield		Unknown
Athens		Unknown
Austin Hill, Rochester	U. S. G. S.	2,274
Austin Hill, West Haven	U. S. G. S.	616
Austin Pond, Hubbardton	U. S. G. S.	468
Averill, Norton	Beers	Unknown
Averys Gore, Essex County		Unknown
Averys Gore, Franklin County		Unknown
Bailey Mills, Reading	U. S. G. S.	1,060
Bakersfield		Unknown
Bald Hill, Pawlet	U. S. G. S.	2,088
Bald Mountain, Bennington	U. S. G. S	2,865
Bald Mountain, Bridgewater	U. S. G. S.	2,380
Bald Mountain, Lincoln	U. S. G. S.	1,620
Bald Mountain, Mendon	U. S. G. S.	2,087
Bald Mountain, West Haven	U. S. G. S.	1,045
Bald Mountain, Woodford	U. S. G. S.	2,885
Baldwin Mountain, Lunenburg	U. S. G. S.	1,981
Ball Mountain, Jamaica	U. S. G. S.	1,745
Baltimore		Unknown
Barber Hill, Charlotte	U. S. G. S.	420

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Barber Mountain, Middletown	U. S. G. S.	1,541
Barber Pond, Pownal	U. S. G. S.	1,100
Bare Hill, Putney	U. S. G. S.	1,240
Bare Hill, Stamford	U. S. G. S.	2,740
Barker Hill, Castleton	U. S. G. S.	1,210
Barker Mountain, Middletown	U. S. G. S.	1,395
Barnard, Village	U. S. G. S.	1,334
Barnard, Morgan School	U. S. G. S.	1,095
Barnard, Lakota Lake	U. S. G. S.	1,885
Barnard, Line Pond	U. S. G. S.	1,460
Barnet	B. & M. R. R.	452
Barnet, School & Town Hall	Aneroid	555
Barnum Hill, Shoreham	U. S. G. S.	496
Barnumville	U. S. G. S., B. M.	785
Barr Hill, Greensboro	U. Vt. Eng.	2,130.9
Barre, Brooks and Main Streets	F. O. L.	596.7
Barre, Grant and Main Streets	F. O. L.	603.6
Barre, High and East Streets	F. O. L.	828.9
Barre, Hotel front piazza	Aneroid	620
Barre, Fountain in Park	Aneroid	615
Barre, Jones Brothers' Plant	F. O. L.	586.8
Barre, Montpelier & Wells River Station		
Barre, Spaulding School	F. O. L.	659
Barre, Spring St. and Maplewood Ave.	F. O. L.	853.5
Barre, Tremont and Parks Sts.	F. O. L.	692.7
Barre, Washington and Liberty Sts.	F. O. L.	709
Barre, Washington and Nelson Sts.	F. O. L.	749
Barton	B. & M. R. R.	945
Barton Mountain, Barton	Beers	953
Bartonsville	Rut. R. R.	487
Basin Harbor, Store	U. S. G. S.	120
Battell Mountain, Ripton	U. S. G. S.	3,471
Baxter Mountain, Sharon	U. S. G. S.	1,530
Bear Mountain, Manchester	U. S. G. S.	3,290
Bear Mountain, Wallingford	U. S. G. S.	2,262
Beebe Plain		Unknown
Beebes Pond, Hubbardton		
Beebe Pond, Hubbardton	U. S. G. S.	622
Beebe Pond, Sunderland	U. S. G. S.	2,320

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Beecher Falls, Canaan	M. C. R. R.	1,093
Beldens, front of Station	U. S. G. S.	330
Bellows Falls, R. R. Station	Fitchburg R. R.	309
Bellows Falls, Church and School Sts.	B. A. R.	354
Bellows Falls, front of High School	Aneroid	365
Bellows Falls, front of Methodist Church	B. A. R.	330
Bellows Falls, front of Post Office	B. A. R.	324
Bellows Falls, Highway Bridge over Conn. River	B. A. R.	336
Bellows Falls, North end of Hyde St.	B. A. R.	489
Bellows Falls, Public Playground	B. A. R.	429
Bellows Falls, West St., near Catholic Cemetery	B. A. R.	382
Belmont, Mount Holly	U. S. G. S.	1,820
Belvidere Center		Unknown
Belvidere Corners		Unknown
Bellevue Hill, St. Albans	U. S. G. S.	1,410
Bennington, Court House	U. S. G. S., B. M.	682
Bennington, National Bank	U. S. G. S., B. M.	672
Bennington, Monument	U. S. G. S., B. M.	873
Bennington, Cor. Main and Bradford Sts.	U. S. G. S.	752.4
Bennington, 4.5 Miles South, D. Touslees	U. S. G. S.	950.2
Bennington, Pine Hill (5 miles south)	U. S. G. S.	968.9
Bennington, 850 feet south of bridge over Deerfield River	U. S. G. S.	1,831
Benson	U. S. G. S.	550
Benson Landing	U. S. G. S.	120
Berkshire		Unknown
Berlin Corners	R. Aneroid	1,125
Berlin Pond	R. Aneroid	965
Berlin Pond, Reservoir Dam	R. Aneroid	893
Berlin Mountain	R. Aneroid	2,425
Berlin, West Hill	R. Aneroid	1,310
Bethel, Track at Station	C. V. R. R.	569

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Bethel, White River Station ...	Aneroid	540
Bethel, Bethel Inn	Aneroid	595
Bethel, High School	Aneroid	600
Bethel, Town Hall	Aneroid	585
Biddle Knob, Pittsford	U. S. G. S.	2,020
Big Pond, Woodford	U. S. G. S.	2,263
Big Spruce Mountain, Arlington	U. S. G. S.	2,510
Billings Pond, Woodford	U. S. G. S.	2,100
Bingham Hill, Bennington	U. S. G. S.	740
Bingham		Unknown
Binghamville, Fletcher		Unknown
Bird Mountain, West Rutland ..	U. S. G. S.	2,210
Black Mountain, Dummerston .	U. S. G. S.	1,269
Black Pond, Hubbardton	U. S. G. S.	625
Blissville, Castleton	U. S. G. S.	480
Blodgett Mountain, Stannard ..		2,500
Bloomfield		Unknown
Bloodroot Mountain, Chittenden	U. S. G. S.	3,520
Blossoms Corners, Pawlet	U. S. G. S.	421
Blueberry Hill, Pittsford	U. S. G. S.	1,724
Blueberry Hill, Plymouth	U. S. G. S.	1,134
Blueberry Ledge, Plymouth	U. S. G. S.	1,040
Blue Ridge Mountain, Mendon .	U. S. G. S.	3,293
Boardman Hill, Clarendon	U. S. G. S.	1,315
Bolton, R. R. Station	C. V. R. R.	338
Boltonville	M. & W. R. R. R.	624
Bomoseen, Lake	U. S. G. S.	413
Bondsville, Mt. Holly	U. S. G. S.	1,280
Bondville, Winhall	U. S. G. S.	1,240
Bowlsville, Mt. Holly	U. S. G. S.	1,300
Bradford, front of Station, top of rail	U. S. G. S.	405
Bradley Hill, Norwich	U. S. G. S.	1,220
Bragg School, Norwich	U. S. G. S.	1,060
Braintree, Station	C. V. R. R.	777
Braintree, Village	U. S. G. S.	787
Branch Pond, Sunderland	U. S. G. S.	2,580
Brandon, R. R. Station	U. S. G. S.	394
Brandon, Bridge over Mill Creek	U. S. G. S.	416.4
Brandon, R. R. Bridge 3.4 miles South	U. S. G. S.	362
Brandon, Brandon Inn	U. S. G. S.	420

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Brandon, Gap Goshen	U. S. G. S.	2,184
Brattleboro, Canal Street School	U. S. G. S.	295
Brattleboro, Elm Street Bridge	U. S. G. S.	245
Brattleboro, Elm and Prospect Sts.	U. S. G. S.	320
Brattleboro, High School, front	U. S. G. S.	295
Brattleboro, Post Office	U. S. G. S.	260
Brattleboro, Union Station, front	U. S. G. S.	250
Brattleboro, Retreat	U. S. G. S.	220
Brattleboro, Reservoir	U. S. G. S.	380
Breakneck Hill, Pomfret	U. S. G. S.	1,100
Breadloaf Inn	U. S. G. S.	1,400
Breadloaf Mountain	U. S. G. S.	3,825
Breese Pond, Hubbardton	U. S. G. S.	555
Bridgewater	U. S. G. S.	820
Bridgewater Center	U. S. G. S.	940
Bridgewater Corners	U. S. G. S.	321
Bridgewater, Riverside School .	U. S. G. S.	954
Bridgewater, Mendall School ..	U. S. G. S.	1,680
Bridgewater, English Mills	U. S. G. S.	800
Bridgewater, Chateaugay	U. S. G. S., B. M.	1,417
Bridport, Village, Grange Hall .	U. S. G. S.	345
Briggs, Bridgewater	U. S. G. S.	940
Briggs Corners, Shaftsbury	U. S. G. S.	1,820
Brigham Hill, Essex	U. S. G. S.	1,032
Brighton		Unknown
Bristol, Casket Factory	U. S. G. S.	510
Bristol, Town Hall	U. S. G. S.	571
Bristol, Flats	U. S. G. S.	376
Bristol, Gilmore Pond	U. S. G. S.	2,020
Bristol, Higgins Pond	U. S. G. S.	1,680
Bristol, R. R. Station	U. S. G. S.	570
Bristol, Hotel	U. S. G. S.	575
Brocklebank Hill, Tunbridge ..	U. S. G. S.	2,120
Brockways	Rut. R. R.	462
Bromley Mountain, Peru	U. S. G. S.	3,260
Brookfield		Unknown
Brookline		Unknown
Brookside		Unknown
Brookville	C. V. R. R.	301
Brooksville, New Haven	U. S. G. S.	240
Brownell Mountain, Williston .	U. S. G. S.	820
Brownington		Unknown

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Brownington Center		Unknown
Brown Pond, Sunderland	U. S. G. S.	2,500
Brownsville		Unknown
Brunswick		Unknown
Bryant Mountain, Wallingford .	U. S. G. S.	1,120
Bryant Mountain, Salisbury ...	U. S. G. S.	1,122
Buck	St. J. & L. C. R. R.	504
Buck Hollow, Fairfax	U. S. G. S.	600
Buck Mountain, Waltham	U. S. G. S.	927
Bucketville, Wardsboro	U. S. G. S.	1,100
Bucks Cobble, Shaftsbury	U. S. G. S.	1,400
Buels Gore		Unknown
Bull Hill, Castleton	U. S. G. S.	920
Bull Hill, Bridgewater	U. S. G. S.	2,320
Burke		Unknown
Burke Mountain	Beers	3,500
Burlington, City Hall, west steps	U. S. G. S.	208
Burlington, Green Mt. Cemetery	U. S. G. S.	313
Burlington, Lake View Cemetery	U. S. G. S.	228
Burlington, Main and Champlain Sts.	U. Vt. E.	150.9
Burlington, Main and St. Paul Sts.	U. Vt. E.	190.7
Burlington, Main and South Union Sts.	U. Vt. E.	225.7
Burlington, Main and Williams Sts.	U. Vt. E.	336.8
Burlington, Main and South Prospect Sts.	U. Vt. E.	364.2
Burlington, Middle Converse Hall	U. Vt. E.	373.5
Burlington, Reservoir	U. S. G. S.	...
Burlington, Union Station	U. S. G. S.	120
Burlington, Weather Bureau ..	U. S. G. S.	381
Burlington, Williams Science Hall, Entrance	U. Vt. E.	369.56
Burlington, Warehouse, Spaulding & Kimball	U. Vt. E.	108.2
Burlington, Mean Water, Lake Champlain	U. S. G. S.	93
Burnhamtown, Monkton	U, S. G. S.	470
Burr Pond, Pittsford	U. S. G. S.	1,180
Burnell Pond, Brandon	U. S. G. S.	500

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Burnt Hill, Hancock	U. S. G. S.	3,120
Burnt Hill, Pawlet	U. S. G. S.	1,080
Burnt Hill, Rupert	U. S. G. S.	2,500
Butlers Corners, Essex	U. S. G. S.	519
Butler Pond, Pittsford	U. S. G. S.	660
Button Hill, Wallingford	U. S. G. S.	2,040
Cabot		Unknown
Cadys Falls, Morristown		Unknown
Calais, Center	R. Aneroid	850
Calais, Bliss Cemetery	R. Aneroid	1,030
Calais, Bliss Pond	R. Aneroid	905
Calais, Kents Corners	R. Aneroid	1,210
Calais, West Hill Church	R. Aneroid	1,335
Calais, Long Meadow Hill	R. Aneroid	2,150
Cambridge, R. R. Station	C. V. R. R.	454
Cambridge, Main St.	Aneroid	498
Cambridge Junction	St. J. & L. C. R. R.	461
Cambridgeport		Unknown
Camels Hump Mountain	Guyot	4,083
	Beers	4,183
Campbell Corners, Strafford ..	U. S. G. S.	840
Camp Brook, Bethel		Unknown
Canaan		Unknown
Cape Lookout Mountain, Goshen	U. S. G. S.	3,298
Carter Hill, Highgate	U. S. G. S.	380
Carmel Mountain, Chittenden ..	U. S. G. S.	3,341
Carpenter Hill, Pownal	U. S. G. S.	1,640
Carver Falls, West Haven	U. S. G. S.	126
Caspian Lake, Greensboro	U. Vt. E.	1,404.4
Castleton, R. R. Station	U. S. G. S.	441
Castleton, Corners	U. S. G. S.	460
Castleton, Blissville	U. S. G. S.	460
Castleton, Hydeville	U. S. G. S.	406
Castleton, Ransomville	U. S. G. S.	700
Castleton, West	U. S. G. S.	440
Catamount Cobble, Sunderland .	U. S. G. S.	2,360
Cavendish, R. R. Station	Rut. R. R.	929
Cedar Beach, South Part	U. S. G. S.	160
Center, Guildhall		Unknown
Center, R. R. Station	C. P. R. R.	774
Centervale, St. Johnsbury	Aneroid	610
Centerville, Hartford	U. S. G. S.	394
Centerville, Hyde Park		Unknown

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Center Rutland, R. R. Station ..	U. S. G. S.	536
Center Hill, Thetford	U. S. G. S.	1,593
Central Mountain, Marlboro ..	U. S. G. S.	2,006
Central Park, Vernon		Unknown
Chaffee Mountain, Chittenden .	U. S. G. S.	2,506
Chamberlin		401
Chamberlain Hill, Richmond ..	U. S. G. S.	920
Champlain, Lake	U. S. G. S.	93
Champlain, Lake	U. S. C. & G. S.	96
Champlain, Lake, High Water .	White	102.7
Champlain, Lake, Low Water, October	White	92.2
Champlain, Lake, Mean 1871-1895	White	96.1
Charlotte, R. R. Station	U. S. G. S.	180
Charlotte, one-fourth mile east of Post Office	U. S. G. S.	252.53
Charlotte, Center	U. S. G. S.	361
Charlotte, Alexanders Corners .	U. S. G. S.	365
Charlestown		Unknown
Chateaugay, Bridgewater	U. S. G. S., B. M.	1,417
Checkerberry Village, Milton ..	U. S. G. S.	780
Chelsea Village	U. S. G. S.	860
Chelsea	Weather Bureau	1,350
Chester, Village	Beers	501
Chester Depot	Rut. R. R.	599
Childs Hill, Thetford	U. S. G. S.	1,306
Childs Mountain, Granville	U. S. G. S.	2,800
Chimney Point	U. S. G. S.	20
Chipman Hill, Middlebury	U. S. G. S.	820
Chippenhook	U. S. G. S.	860
Chiselville, Sunderland	U. S. G. S.	800
Chittenden, Michigan Camp	U. S. G. S.	1,400
Chittenden, Steam Mill School .	U. S. G. S.	1,500
Chittenden, Village	U. S. G. S.	1,180
Chittenden, North	U. S. G. S.	1,000
Choate Pond, Orwell	U. S. G. S.	960
Christian Hill, Bethel		Unknown
Chrysotile	Aneroid	1,210
Clarendon	U. S. G. S.	580
Clark Mountain, Tinmouth	U. S. G. S.	1,961
Clark Hill, West Rutland	U. S. G. S.	1,600
Clark, Sutton		Unknown

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Cleveland Hall, Pawlet	U. S. G. S.	1,360
Cloverdale		Unknown
Coates Island, Malletts Bay	U. S. G. S.	160
Cobb Hill, Bridgewater	U. S. G. S.	1,960
Cobble Hill, Londonderry	U. S.G. S.	1,907
Cobble Hill, Milton	U. S. G. S.	860
Cobble Hill, Rochester	U. S. G. S.	1,080
Cobble Hill, Wells	U. S. G. S.	1,510
Cobble Hill, Weston	U. S. G. S.	907
Colbyville, Waterbury		Unknown
Colchester Center	U. S. G. S.	274
Colchester, R. R. Station	U. S. G. S., B. M.	328
Colchester Pond	U. S. G. S.	366
Cold River, Clarendon	U. S. G. S.	553
College Hill, Jamaica	U. S. G. S.	2,051
Colton Hill, Vershire	U. S. G. S.	2,412
Comtois Hill, Shrewsbury	U. S. G. S.	2,020
Conicut, Newbury		Unknown
Concord, S. E. Portion	U. S. G. S.	1,190
Cooks Hill, Greensboro	U. Vt. E.	1,730.7
Cooks Hill, Stamford	U. S. G. S.	1,685
Cooper Hill, Dover	U. S. G. S.	2,606
Copperas Hill, Shrewsbury	U. S. G. S.	1,861
Copperas Hill, Strafford	U. S. G. S.	1,160
Copperfield	U. S. G. S.	960
Copper Flat, Strafford	U. S. G. S.	860
Corinth		Unknown
Cornwall, Library	U. S. G. S.	365
Cornwall, Village, Town Hall ..	U. S. G. S.	374
Cornwall, Bridge over Otter Creek, three miles east of village	U. S. G. S.	349.5
Corporation Mountain, Chittenden	U. S. G. S.	3,000
Coventry		Unknown
Coy Mount, Wells	U. S. G. S.	2,060
Craftsbury Corners	Beers	1,159
Cream Hill, Bridport	U. S. G. S.	420
Crookhite Hill, Monkton	U. S. G. S.	440
Crystal Pond, Barton	Beers	988
Cudding Hill, Shoreham	U. S. G. S.	500
Curtis Hill, Tunbridge	U. S. G. S.	1,561
Cushman Hill, Georgia	U. S. G. S.	1,087

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Cushman Mountain, Rochester	U. S. G. S.	2,791
Cutler Pond, Highgate	U. S. G. S.	250
Cutler Pond, Williamstown	Aneroid	880
Cuttingsville	U. S. G. S.	1,047
Dailey Hollow, Bridgewater	U. S. G. S.	1,150
Dana Hill, Pomfret	U. S. G. S.	1,380
Danby	U. S. G. S.	680
Danby Four Corners	U. S. G. S.	1,440
Danby Four Corners	U. S. G. S.	1,360
Danby Hill	U. S. G. S.	2,112
Danby Pond	U. S. G. S.	1,280
Danville, Station	St. J. & L. C. R. R.	1,341
Danville, Post Office	Aneroid	1,420
Davis Bridge	U. S. G. S.	1,360
Davison Hill, Strafford	U. S. G. S.	1,740
Deer Knoll, Manchester	U. S. G. S.	1,620
Delano Hill, Shoreham	U. S. G. S.	610
Delectable Mountain, Barnard	U. S. G. S.	2,660
Derby Center, Post Office	Aneroid	1,030
		975
Derby Line	B. & M. R. R.	1,042
Deweys Mills	U. S. G. S., B. M.	627
Diamond Hill, Milton	U. S. G. S.	540
Dome, Pownal	U. S. G. S.	2,754
Dorset	U. S. G. S.	940
Dorset, East	U. S. G. S., B. M.	788
Dorset Hill	U. S. G. S.	2,860
Dorset Mountain	U. S. G. S.	3,436
Dorset Peak, Danby	U. S. G. S.	3,804
Dorset Pond	U. S. G. S.	720
Dorset, South	U. S. G. S.	920
Dothan, Hartford	U. S. G. S.	940
Dover, Church	U. S. G. S.	1,895
Dover, East	U. S. G. S.	1,100
Dover, West	U. S. G. S.	1,720
Dow, R. R. Station	St. J. & L. C. R. R.	1,411
Dow Hill, Hinesburg	U. S. G. S.	1,231
Dow Pond, Middlebury	U. S. G. S.	440
Dummerston, Village	U. S. G. S.	740
Dummerston, Church	U. S. G. S.	778
Dummerston, R. R. Station	U. S. G. S.	260
Dunmore, Lake, Salisbury	U. S. G. S.	571
Dunmore, Lake, Hotel	U. S. G. S.	578

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Dutch Hill, Danby	U. S. G. S.	2,480
Duxbury		Unknown
Eagle Ledge, Vershire	U. S. G. S.	1,859
Eagle Mountain, Milton	U. S. G. S.	600
East Alburg	U. S. G. S., B. M.	116
East Arlington	U. S. G. S.	740
East Barnard		Unknown
East Barnet		Unknown
East Barre		Unknown
East Berkshire	C. V. R. R.	434
East Bethel		Unknown
East Braintree		Unknown
East Brighton	G. T. R. R.	1,159
East Burke	Aneroid	950
East Calais	Aneroid	8.30
East Cambridge		Unknown
East Charleston		Unknown
East Charlotte	U. S. G. S.	375
East Clarendon	U. S. G. S.	780
East Concord	~~St. J. & L. C. R. R.~~ M.C.R.R.	876
East Corinth		Unknown
East Craftsbury		Unknown
East Dorset	U. S. G. S.	788
East Dover, Church	U. S. G. S.	1,115
East Enosburg		Unknown
East Fairfield	St. J. & L. C. R. R.	371
East Fletcher		Unknown
East Franklin		Unknown
East Georgia	U. S. G. S., B. M.	354
East Granville		Unknown
East Hardwick	St. J. & L. C. R. R.	1,031
East Haven		Unknown
East Highgate	St. J. & L. C. R. R.	356
East Hill, Tunbridge	U. S. G. S.	1,540
East Hubbardton	U. S. G. S.	960
East Jamaica		Unknown
East Kansas, Sunderland	U. S. G. S.	940
East Middlebury, Hotel	U. S. G. S.	475
East Middlebury, three-quarters of a mile east at road corners	U. S. G. S.	782.5
East Monkton	U. S. G. S.	660
East Montpelier, Bridge	Aneroid	430-650
East Mountain, Guildford	Beers	1,424

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
East Mountain, Mendon	U. S. G. S.	2,390
East Mountain, Sherburne	U. S. G. S.	2,812
East Mountain, Starksboro	U. S. G. S.	1,520
East Peacham	Aneroid	940
East Pittsford	U. S. G. S.	1,000
East Poultney	U. S. G. S.	480
East Putney, Village	U. S. G. S.	380
East Putney, R. R. Station	U. S. G. S.	280
East Randolph, Village		691
East Richford		Unknown
East Rupert	U. S. G. S.	840
East Ryegate	B. & M. R. R.	475.35
East St. Johnsbury	St. J. & L. C. R. R.	786
East Shoreham	U. S. G. S.	276
East Swanton	U. S. G. S.	160
East Thetford	B. & M.& R. R.	405
East Wallingford	U. S. G. S.	1,234
East Wells	U. S. G. S.	1,060
East Wilmington	U. S. G. S.	1,820
Eden	Aneroid	1,020
Eden Mills	Aneroid	1,210
Eden Lake	Aneroid	1,130
Edgerton Hill, Pawlet	U. S. G. S.	1,220
Egg Mountain, Sandgate	U. S. G. S.	2,510
Elbow, Woodford	U. S. G. S.	2,587
Elkhurst, Station	C. P. R. R.	672.7
Elligo Pond, Craftsbury	Aneroid	890
Elligo Pond, Lower	Aneroid	860
Elmore		Unknown
Ely, Top of rail front of Station	C. P. R. R.	430
Emerson, Rochester	U. S. G. S.	800
English Mills, Woodstock	U. S. G. S.	840
Enosburg Falls	C. V. R. R.	439
Enosburg Falls	Weather Bureau	436
Eolus Mountain, Dorset	U. S. G. S.	804
Equinox Mountain, Manchester	U. S. G. S.	3,816
Essex, Brigham Hill School ...	U. S. G. S.	640
Essex Center, Village	U. S. G. S.	492
Essex, Beecher School	U. S. G. S.	460
Essex, Pages Corner	U. S. G. S.	585
Essex, Butlers Corners	U. S. G. S.	519
Essex, Warner School	U. S. G. S.	520
Essex Junction, R. R. Station ..	U. S. G. S.	358

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Essex Junction, old Brick School	U. S. G. S.	357.5
Ethan Allen Park, Burlington, Base of Tower	U. S. G. S.	300
Evarts, North Hartland	U. S. G. S., B. M.	383
Evansville, Brownington	U. S. G. S.	349
Fairfax, Village	U. S. G. S.	349
Fairfax, School 11	U. S. G. S.	460
Fairfield, R. R. Station	St. J. & L. C. R. R.	356
Fairfield Pond	U. S. G. S.	540
Fairfield, School 11	U. S. G. S.	460
Fairfield, School 8	U. S. G. S.	852
Fairfield, Swamp School	U. S. G. S.	700
Fair Haven, Village Square ...	U. S. G. S.	400
Fair Haven, R. R. Station	U. S. G. S.	360
Fair Haven, Inman Pond	U. S. G. S.	640
Fairlee, in front of R. R. Station, top of rail	U. S. G. S.	435.5
Fairlee, 1.6 miles s. w. of village west of track, B. M.	U. S. G. S.	413.6
Fairlee, Beanville	U. S. G. S.	860
Fairmount, East Montpelier ...	M. & W. R. R.	720
Fan Hill, Wells	U. S. G. S.	1,731
Farmingdale, Middlebury	U. S. G. S.	383
Fays Corners, Richmond	U. S. G. S., B. M.	563
Fayston		Unknown
Fayville, Glastenbury	U. S. G. S.	1,840
Felchville		Unknown
Ferdinand		Unknown
Fenville, Leicester	U. S. G. S., B. M.	583
Fern Lake, Leicester	U. S. G. S.	571
Ferrisburg, Foundation of Town Hall	U. S. G. S.	217
Ferrisburg, North	U. S. G. S., B. M.	168
Fisk, Isle La Motte	U. S. G. S.	120
Fishers Switch	Rut. R. R.	317
Fitzdale, Lunenburg		Unknown
Flat Rock, Clarendon	U. S. G. S.	1,285
Fletcher	St. J. & L. C. R. R.	424
Fletcher, Bridport	U. S. G. S.	373
Florence	U. S. G. S.	380
Florona Mountain, Monkton ...	U. S. G. S.	660
Forbes Hill, West Haven	U. S. G. S.	540
Forestdale	U. S. G. S.	595

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Fort Ethan Allen, Colchester ..	U. S. G. S.	308
Fort Ethan Allen 100 feet east of station	U. S. G. S.	311
Foundryville, Hartland	Beers	430
Franklin	Beers	430
Freestone Hill, Bridgewater ..	U. S. G. S.	2,160
Fox Pond, Wallingford	U. S. G. S.	580
Fuller Mountain, Ferrisburg ..	U. S. G. S.	920
Gallup Hill, Montpelier		Unknown
Gallup Mills, Victory		Unknown
Garfield, Hyde Park		Unknown
Garland Camp, Pittsfield	U. S. G. S.	1,381
Gaskill, Waterford		Unknown
Gassetts, Station	Beers	715
Gaysville	Aneroid	690
Georgia Center	U. S. G. S.	385
Georgia, Everett School	U. S. G. S.	160
Georgia, Plains	U. S. G. S.	259
Georgia, School No. 2	U. S. G. S.	280
Gile Mountain, Norwich	U. S. G. S.	1,917
Gilette Hill, Hartford	U. S. G. S.	1,220
Gillespie Mountain, Granville ..	U. S. G. S.	2,928
Gilman Hill, Vershire	U. S. G. S.	2,065
Gilmore Pond, Bristol	U. S. G. S.	2,000
Ginseng Hill, Brattleboro	U. S. G. S.	1,556
Glastenbury Mountain, Glastenbury	U. S. G. S.	3,764
Glebe Mountain, Londonderry ..	U. S. G. S.	2,944
Glen Lake, Castleton	U. S. G. S.	480
Glenton	White	526
Glover		Unknown
Goodhue Ledge, Vershire	U. S. G. S.	1,820
Gorhamtown, Poultney	U. S. G. S.	660
Goshen, Church, south end	U. S. G. S.	1,136
Goshen Four Corners	U. S. G. S.	1,408
Goshen Mountain	U. S. G. S.	3,266
Gove Hill, Thetford	U. S. G. S.	1,362
Government Hill, Sudbury	U. S. G. S.	1,075
Governor Mountain, Guilford ..	U. S. G. S.	1,823
Grafton		Unknown
Granby		Unknown
Grand Isle, Village	U. S. G. S.	160

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Grand Isle, Iodine Springs House	U. S. G. S.	120
Grand Isle, Ladds Point	U. S. G. S.	140
Grand Isle, Ridge between Station and McBride Bay, highest	U. S. G. S.	220
Grangerville, Pittsford	U. S. G. S.	500
Grandmadam Hill, Bridgewater	U. S. G. S.	1,980
Granite Hill, Wallingford	U. S. G. S.	2,007
Graniteville		Unknown
Grannyhand Hill, Strafford	U. S. G. S.	1,710
Grant, Westminster		Unknown
Granville, Braintree Gap	U. S. G. S.	2,383
Granville, Village	U. S. G. S., B. M.	1,013
Granville, North Hollow School	U. S. G. S.	1,495
Granville, South Hollow School	U. S. G. S.	1,439
Granville, Texas School	U. S. G. S.	1,845
Granville, West Hill School ...	U. S. G. S.	1,351
Grass Mountain, Arlington	U. S. G. S.	2,800
Grass Pond, Plymouth	U. S. G. S.	1,560
Green Hill, Wallingford	U. S. G. S.	1,213
Green Mount, Mount Tabor ...	U. S. G. S.	2,340
Green Mountain, Wallingford ..	U. S. G. S.	2,509
Green Peak, Dorset	U. S. G. S.	3,436
Green River, Church	U. S. G. S., B. M.	749
Greensboro, Station	St. J. & L. C. R. R.	1,146
threshold	U. Vt. E.	1,247.9
Greensboro, Catholic Church,		
Greensboro, step, north end of P. O.	U. Vt. E.	1,383.5
Greensboro, Caspian Lake House, lower step, S. E. corner	U. Vt. E.	1,391.3
Greensboro, Lake House, top of stone post in front	U. Vt. E.	1,463.4
Greensboro, Caspian Lake at water	U. Vt. E.	1,404.4
Greensboro, lower step, south end of Town Hall	U. Vt. E.	1,420.5
Greensboro Mills		Unknown
Greensboro, in front of H. H.	U. Vt. E.	1,420.5
Smiths	U. Vt. E.	1,386
Greens Corners, Swanton	U. S. G. S.	405

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Green River, Guilford	U. S. G. S.	740
Griffith, Mt. Tabor	U. S. G. S.	1,640
Greenvale, Thetford		Unknown
Griggs Mountain, Norwich	U. S. G. S.	1,800
Groton, Station	M. & W. R. R. R.	773
Groton Pond	M. & W. R. R. R.	1,094
Grout, Station	B. & M. R. R.	251
Grout Pond, Stratton	U. S. G. S.	2,225
Grove, Halifax	U. S. G. S.	1,460
Guildhall	M. C. R. R.	874
Guildhall Falls	Beers	833
Guilford, Church	U. S. G. S.	410
Guilford Center	U. S. G. S.	708
Guilford, Green River	U. S. G. S.	740
Guilford, Hinesburg	U. S. G. S.	940
Hale Hollow, Plymouth	U. S. G. S.	960
Hale Mountain, Shaftsbury	U. S. G. S.	1,420
Halfmoon Pond, Hubbardton	U. S. G. S.	586
Halifax, Church	U. S. G. S.	1,900
Halifax, Grove	U. S. G. S.	1,360
Hammond Hill, Ht. Holly	U. S. G. S.	1,721
Hancock, Village, cross roads	U. S. G. S.	912
Hancock, Branch School	U. S. G. S.	1,040
Hancock, Middlebury Gap	U. S. G. S.	2,149
Hancock Mountain, Hancock	U. S. G. S.	2,089
Hanksville, Huntington		
Hardwick	St. J. & L. C. R. R.	861
Hardwick Hollow	Beers	720
Harmony Hill, Woodford	U. S. G. S.	2,325
Harrington Hill, Danby	U. S. G. S.	2,318
Harrington Cobble, Shaftsbury	U. S. G. S.	1,460
Hartford, Village	U. S. G. S.	400
Hartford, Birch School	U. S. G. S.	941
Hartford, Center School	U. S. G. S., B. M.	834
Hartford, Centerville	U. S. G. S., B. M.	394
Hartford, Deweys Mills, Station	U. S. G. S.	550
Hartford, Dothan	U. S. G. S.	840
Hartford, Podunk	U. S. G. S.	400
Hartford, Jericho	U. S. G. S.	1,065
Hartland, R. R. Station	U. S. G. S.	441
Hartland, Village	U. S. G. S.	582
Hartland, main road, 3½ miles south of Taftsville	U. S. G. S., B. M.	954

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Hartland, Four Corners, Church	U. S. G. S.	637.5
Harvey, Danville		Unknown
Harvey Pond	Aneroid	870
Haverhill, R. R. Station	B. & M. R. R.	404
Haynes Hill, Middletown	U. S. G. S.	1,260
Haystack Mountain, Pawlet	U. S. G. S.	1,919
Haystack Mountain, Wilmington	U. S. G. S.	3,462
Haystack Pond, Wilmington	U. S. G. S.	2,660
Healdville, Station	Rut. R. R.	1,432
Heartwellville, east of P. O.	U. S. G. S.	1,784
Heartwellville, Readsboro, 2½ miles north on main road	U. S. G. S.	2,446
Heartwellville, iron bridge	U. S. G. S.	1,363
Hedgehog Hill, Mt. Holly	U. S. G. S.	2,295
Herrick Mountain, Ira	U. S. G. S.	2,727
Hewetts Corners, Pomfret	U. S. G. S.	1,140
Highgate, Post Office	U. S. G. S.	225
Highgate, North Gore School	U. S. G. S.	302
Highgate, South Gore School	U. S. G. S.	304
Highgate Center	U. S. G. S., B. M.	310
Highgate Falls	U. S. G. S.	300
Highgate Springs	U. S. G. S.	127
High Knob, Shaftsbury	U. S. G. S.	1,320
High Hill, Pawlet	U. S. G. S.	1,318
Highley Hill, Marlboro	U. S. G. S.	2,301
High Pond, Sudbury	U. S. G. S.	820
Hinesburg, Church	U. S. G. S.	922
Hinesburg, Town Hall	U. S. G. S.	343
Hinesburg, Pond	U. S. G. S.	684
Hinesburg, Guilford	U. S. G. S.	940
Hinkum Pond	U. S. G. S.	717
Hoag Mountain, Danby	U. S. G. S.	2,240
Hogback Mountain, Bristol	U. S. G. S.	1,850
Hogback Mountain, Goshen	U. S. G. S.	2,290
Hogback Mountain, Marlboro	U. S. G. S.	2,347
Hogback Mountain, Monkton	U. S. G. S.	1,620
Holden, North Chittenden	U. S. G. S.	1,000
Holt Hill, Chelsea	U. S. G. S.	1,775
Horrid Mountain, Goshen	U. S. G. S.	3,140
Horton Pond, Hubbardton	U. S. G. S.	488
Howard Hill, Benson	U. S. G. S.	661
Houghtonville		Unknown
Hubbard Hill, Thetford	U. S. G. S.	1,682

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Hubbardton, Village	U. S. G. S.	433
Hubbardton, Huff Pond	U. S. G. S.	772
Huffs Crossing, Orwell	U. S. G. S.	228
Hunger Mountain, Barnard ...	U. S. G. S.	2,440
Hurricane Hill, Woodstock	U. S. G. S.	1,160
Hyde Manor, Sudbury	U. S. G. S.	823
Hyde Park, Station	St. J. & L. C. R. R.	576
Hydeville, Castleton	U. S. G. S.	406
Independence Mountain, Shoreham	U. S. G. S.	300
Indian Hill, Pawlet	U. S. G. S.	1,007
Inman Pond, Fairhaven	U. S. G. S.	640
International Boundary, northwest of Richford	White	495
International Boundary, northeast of Richford	White	508
Inwood, Barnet		
Ira	U. S. G. S.	840
Irasburg	Beers	875
Island Pond, Station	G. T. R. R.	1,178
Isle La Motte, Village	U. S. G. S.	200
Isle La Motte, The Head	U. S. G. S.	240
Isle La Motte, Light House	U. S. G. S.	120
Isle La Motte, Fisk	U. S. G. S.	120
Jacksonville, Whitingham, Village	U. S. G. S.	1,400
Jamaica, Village	U. S. G. S.	700
Jamaica, Rawsonville	U. S. G. S.	1,070
Jamaica, West	U. S. G. S.	1,540
Jay		Unknown
Jay Peak	U. S. C. & G. S.	3,861
Jeffersonville, Station	C. V. R. R.	460
Jeffersonville, Hotel	Aneroid	510
Jericho, Center		Unknown
Jericho, Station	U. S. G. S.	
Jericho, Bridge at Corners	U. S. G. S.	500
Jericho, Church	Aneroid	580
Jericho, Hartford	U. S. G. S.	1,065
Jilson Hill, Whitingham	U. S. G. S.	2,251
Jockey Hill, Shrewsbury	U. S. G. S.	2,671
Joes Pond, Cabot	Aneroid	1,544
Johnson, Station	St. J. & L. C. R. R.	531
Johnson, Hotel	Aneroid	510

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Johnson Pond, Orwell	U. S. G. S.	445
Jones Hill, Charlotte	U. S. G. S.	600
Jones Mountain, Rochester ...	U. S. G. S.	2,096
Jonesville, Station	C. V. R. R.	322.5
Kansas, Sunderland	U. S. G. S.	840
Kelley Stand, Sunderland	U. S. G. S.	2,240
Kent Hill, Hartland	U. S. G. S.	1,660
Kibling Hill, Strafford	U. S. G. S.	1,424
Killington Mountain	U. S. G. S.	4,241
Kirby		Unknown
Kirby Peak, Ripton	U. S. G. S.	3,000
Lake, Station	G. T. R. R.	1,342
Lake Bomoseen	U. S. G. S.	413
Lake Champlain, Wharf, C. T. Co., July, 1904	U. S. G. S.	94.39
Lake Dunmore	U. S. G. S.	571
Lake Memphremagog	C. P. R.	665
Lake Morey		Unknown
Lake Saint Catherine	U. S. G. S.	477
Lake Seymour		Unknown
Lake Willoughby	Aneroid	1,200
Lakeside	M. & W. R. R. R.	1,094
Lakota Lake, Barnard	U. S. G. S.	1,885
Landgrove	U. S. G. S.	1,280
Lanesboro	M. & W. R. R. R.	1,347
Lemington		Unknown
Lewiston, Norwich	U. S. G. S.	440
Leicester Junction, crossing north of station	U. S. G. S.	353
Lewis		Unknown
Liberty Hill, Pittsfield	U. S. G. S.	1,620
Lillieville, Stockbridge		
Lilly Hill, Danby	U. S. G. S.	1,500
Lilly Pond, Vernon	U. S. G. S.	380
Lincoln, opposite Lumber Company's store	U. S. G. S.	971
Lincoln, Bridge	U. S. G. S.	758
Lincoln Mountain	U. S. C. & G. S.	4,024
Lincoln Hill, Wells	U. S. G. S.	1,280
Line Pond, Barnard	U. S. G. S.	1,460
Line Pond, Stockbridge	U. S. G. S.	1,380
Linwood	Aneroid H. L. F.	495
Little Ascutney	Beers	1,200

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Little Killington, Mendon	U. S. G. S.	3,951
Little Pico Mountain, Rochester	U. S. G. S.	2,115
Little Pico, Sherburne	U. S. G. S.	3,134
Little Pond, Benson	U. S. G. S.	502
Little Pond, Wells	U. S. G. S.	
Little Pond, Winhall	U. S. G. S.	2,390
Little Round Top, Stratton	U. S. G. S.	3,440
Londonderry	U. S. G. S.	1,100
Little Wilcox Peak, Pittsfield ..	U. S. G. S.	2,729
Long Pond, Milton	U. S. G. S.	297
Lookoff Mountain, Chittenden .	U. S. G. S.	2,600
Lost Lake, Georgia	U. S. G. S.	480
Lowell	Aneroid	900
Lowell Lake, Londonderry	U. S. G. S.	1,200
Lower Cabot		Unknown
Lower Granville	U. S. G. S.	962
Lower Rochester	U. S. G. S.	800
Lower Waterford		Unknown
Ludlow, Station	Rut. R. R.	1,064
Ludlow, Village		Unknown
Ludlow Mountain, Mt. Holly ..	U. S. G. S.	3,372
Lunenburg	U. S. G. S.	844
Lunenburg, Bridge, M. C. R. R.	U. S. G. S.	846
Lyford Pond, Walden	Beers	1,692
Lyndon		Unknown
Lyndonville, Station	B. & M. R. R.	727
Lyndon Center		Unknown
McIndoes, Station	Beers	488
McIndoes Falls	B. & M. R. R.	441
MacIntyre, Sunderland	U. S. G. S.	2,140
MacMaster Hill, Strafford	U. S. G. S.	1,960
Maidstone	M. C. R. R.	865
Malletts Head, Colchester	U. S. G. S.	300
Manchester, Village St.	U. S. G. S.	880
Manchester Center	U. S. G. S.	740
Manchester Depot	U. S. G. S.	690
Manchester, Beartown	U. S. G. S.	1,400
Manchester, Barnumville	U. S. G. S.	740
Mansfield Mountain, Chin	U. S. C. & G. S.	4,406
Mansfield Mountain, Nose	U. S. C. & G. S.	4,075
Maple Hill, Shaftsbury	U. S. G. S.	1,706
Maple Hill, Woodford	U. S. G. S.	2,740
Maquam	U. S. G. S.	108

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Markham Mountain, Andover ..	U. S. G. S.	2,489
Markham Mountain, Weston ..	U. S. G. S.	2,481
Marlboro, Church	U. S. G. S.	1,736
Marlboro, highest point in road to Wilmington over Hogback	U. S. G. S.	2,210
Marshfield, Station	M. & W. R. R. R.	1,140
Marshfield, Hotel	Aneroid	750
Marsh Hill, Ferrisburg	U. S. G. S.	340
Mason Hill, Pownal	U. S. G. S.	1,660
Mason Hill, Sherburne	U. S. G. S.	260
Masters Mountain, Rupert	U. S. G. S.	2,410
Mechanicsville, Hinesburg	U. S. G. S.	436
Mechanicsville, Mt. Holly	U. S. G. S.	1,820
Mecawee Pond, Reading	U. S. G. S.	1,380
Meetinghouse Hill, Norwich ...	U. S. G. S.	1,201
Meetinghouse Hill, Woodstock .	U. S. G. S.	1,660
Memphremagog, Lake, Feb. 3, 1892	White	682
Mempremagog, Lake, July 4, 1916	C. P. R.	685
Mendon Peak, Mendon	U. S. G. S.	3,837
Merrill Hill, Chelsea	U. S. G. S.	1,390
Middlebury, Addison House ...	U. S. G. S.	390
Middlebury, Battell Block	U. S. G. S.	366
Middlebury, New College Chapel	U. S. G. S.	455
Middlebury, Old College Chapel	U. S. G. S.	421
Middlebury, R. R. Station	U. S. G. S.	355
Middlebury, Women's Dormitory	U. S. G. S.	457
Middle Mountain, Pawlet	U. S. G. S.	1,965
Middlesex, Station	C. V. R. R.	534
Middletown Springs	U. S. G. S.	887
Miles Mountain, Concord		2,470
Miles Pond	St. J. & L. C. R. R.	1,016
Miller Pond, Strafford	U. S. G. S.	1,320
Mill Village, Vershire	U. S. G. S.	1,040
Milton, Village	U. S. G. S., B. M.	356
Milton, Keelers Hotel	U. S. G. S.	300
Milton, School No. 5	U. S. G. S., B. M.	324
Milton, School No. 12	U. S. G. S.	200
Miltonboro	U. S. G. S.	
Milton Pond	U. S. G. S.	834
Mitchell Hill, Sharon	U. S. G. S.	900
Minister Hill, Sandgate	U. S. G. S.	2,117

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Missisquoi	White	508
Moffit Mountain, Sandgate	U. S. G. S.	2,278
Mollys Pond, Cabot	U. S. G. S.	1,620
Monastery Mountain, Hancock	U. S. G. S.	3,222
Monkton, Village	U. S. G. S., B. M.	533
Monkton Pond	U. S. G. S.	491
Monkton Ridge	U. S. G. S.	598
Montague Hill, Bridgewater	U. S. G. S.	2,500
Montgomery		Unknown
Montgomery Center		Unknown
Montpelier, Wells River Station, track	G. A. R.	533
Montpelier, Cent. Vt. Station	G. A. R.	528.5
Montpelier Center	R. Aneroid	1,050
Montpelier, City Hall base of columns	G. A. R.	535.8
Montpelier, bolt north side of east steps, Post Office	U. S. G. S.	529.6
Montpelier, Hospital water table	G. A. R.	661.4
Montpelier, Elm & Springs Sts., top of hydrant	G. A. R.	532.5
Montpelier, Arsenal Building, hydrant	G. A. R.	670
Montpelier, Main & State Sts.	G. A. R.	530
Montpelier, front of State House, top of steps	G. A. R.	560
Montpelier, stone post, s. w. corner Seminary Campus	G. A. R.	669.7
Montpelier Junction	C. V. R. R.	522
Moosalamoo Mountain	U. S. G. S.	2,659
Moores Ponds, Plymouth	U. S. G. S.	1,320
Moosehorn Mountain, Wells	U. S. G. S.	1,845
Morrisville, Station	B. & M. R. R.	646
Morrisville, Village	Aneroid, H. L. F.	610
Morrisville, Park	Aneroid, H. L. F.	676
Morrisville, Hotel	Aneroid	667
Moretown		Unknown
Morgan		Unknown
Morgan Center		Unknown
Morgan Mountain, Middletown	U. S. G. S.	2,659
Morgan Peak, Bridgewater	U. S. G. S.	2,600
Morrill Mountain, Strafford	U. S. G. S.	1,702
Morristown		Unknown

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Morses Line, Franklin		Unknown
Moscow, Stowe		Unknown
Mother Merrick Mountain, Sandgate	U. S. G. S.	3,320
Mount Holly	U. S. G. S.	1,398
Mountain Mills		Unknown
Mount Pleasant, Leicester	U. S. G. S.	920
Mount Prospect, Woodford	Beers	2,690
Mount Tabor	U. S. G. S.	700
Mount Tom, Plymouth	U. S. G. S.	2,160
Mud Pond, Leicester	U. S. G. S.	585
Mud Pond, Orwell	U. S. G. S.	740
Mud Pond, Sharon	U. S. G. S.	860
Mud Pond, Stamford	U. S. G. S.	2,760
Mutton Hill, Charlotte	U. S. G. S.	428
Neal Pond, Lunenburg	U. S. G. S.	1,195
Netop Mountain, Dorset	U. S. G. S.	3,120
Newark		Unknown
New Boston, Norwich	U. S. G. S.	500
Newbury, Station	B. & M. R. R.	418
Newfane, Church	U. S. G. S.	571
Newfane, Hill	U. S. G. S.	1,630
Newfane, Williamsville	U. S. G. S.	540
New Haven, Brooksville	U. S. G. S.	240
New Haven, Church	U. S. G. S., B. M.	454
New Haven Junction	U. S. G. S.	282
New Haven, Mills	U. S. G. S.	338
New Haven Falls	U. S. G. S.	300
New Haven, Spring Grove	U. S. G. S.	408
Newport, Station, rail in front of order board	C. P. R. R.	670.9
Newport, Catholic Church	Aneroid	805
Newport Center, Station	C. P. R. R.	777.4
Nickwaket Mountain, Chittenden	U. S. G. S.	2,720
North Bennington	U. S. G. S.	640
Northboro, Thetford		Unknown
North Bridgewater	U. S. G. S.	1,264
North Calais		Unknown
North Clarendon	U. S. G. S.	680
North Chittenden	U. S. G. S.	1,000
North Concord	St. J. & L. C. R. R.	1,091
North Derby		Unknown
North Dorset	U. S. G. S.	700

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
North Duxbury	C. V. R. R.	378.5
North Enosburg		Unknown
North East Mountain, Wells ..	U. S. G. S.	2,125
North Ferrisburg, Village	U. S. G. S., B. M.	163
Northfield, Station	C. V. R. R.	732
Northfield, Parade Ground	A. E. W.	855
Northfield	Weather Bureau	876
Northfield Falls	Aneroid	660
North Hartland	U. S. G. S., B. M.	383
North Hartland, 600 feet west of station	U. S. G. S.	383
North Hartland, 11 miles north of station, 540 feet north of guide post to Windsor	U. S. G. S.	350
North Hero, Hotel	U. S. G. S.	120
North Hero, Bow Arrow Point	U. S. G. S.	140
North Hero, Hibbard Point ..	U. S. G. S.	140
North Hero, Pelot Point	U. S. G. S.	140
North Hyde Park	Aneroid	770
North Landgrove	U. S. G. S.	1,260
North Montpelier, Iron Bridge .	Aneroid	670
North Orwell	U. S. G. S.	573
North Pawlet	U. S. G.S.	602
North Pomfret	U. S. G. S.	800
North Pond, Bristol	U. S. G. S.	2,100
North Pond, Chittenden	U. S. G. S.	2,320
North Pond, Marlboro	U. S. G. S.	1,540
North Pownal	U. S. G. S.	560
North Rupert	U. S. G. S.	745
North Sheldon	C. V. R. R.	386
North Sherburne	U. S. G. S.	1,260
North Springfield		Unknown
North Shrewsbury	U. S. G. S.	1,746
North Thetford, Station, top of rail	B. & M. R. R.	396
North Thetford, iron bridge a little southwest	U. S. G. S.	399
North Troy, Station	C. P. R. R.	603
North Troy, Hotel	Aneroid	610
North Tunbridge	U. S. G. S.	640
North Underhill	C. V. R. R.	720
North Williston, Brick Mill east of Station	U. S. G. S.	305

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
North Windham		Unknown
North Wolcott		Unknown
Norton Hill, Shaftsbury	U. S. G. S.	1,920
Norton Mills, Station	G. T. R. R.	1,252
Norton Mills, International Boundary	White	1,250
Norwich, Station	U. S. G. S.	400
Norwich, near corner Mechanic and Main Sts.	U. S. G. S.	536
Notown, Stockbridge	U. S. G. S.	1,300
Noyes Pond, Chittenden	U. S. G. S.	2,320
Nulhegan, Station, river crossing	G. T. R. R.	1,121
Nulhegan, Station, 157.9 miles from Montreal		923
Oakland, Station, 162.4 miles from Montreal	U. S. G. S.	440
Ohio Hill, Bridgewater	U. S. G. S.	2,380
Old City, Stafford	U. S. G. S.	1,260
Old Knob, Poultney	U. S. G. S.	1,150
Old Sixty Hill, Granville	U. S. G. S.	1,780
Olympus Mountain, Bethel		2,506
Orcutt Hill, Pawlet	U. S. G. S.	1,958
Orange		Unknown
Orleans, Station	Aneroid	740
Orleans, 1 mile from station, bridge 76	B. & M. R. R.	741.11
Orwell	U. S. G. S.	385
Orwell, Hotel	U. S. G. S.	400
Owls Head, Dorset	U. S. G. S.	2,535
Owls Head, Richmond	U. S. G. S.	1,160
Paine Mountain	A. E. W.	2,360
Panton, Village	U. S. G. S.	200
Papermill Village, Bennington .	U. S. G. S.	640
Parker Hill, Castleton	U. S. G. S.	575
Passumpsic, Station, sill of waiting room	B. & M. R. R.	531.14
Patch Pond, Mount Holly	U. S. G. S.	1,750
Pattern, Pawlet	U. S. G. S.	860
Patterson Mountain, Vershire ..	U. S. G. S.	2,321
Pawlet	U. S. G. S.	680
Pawlet Mountain	U. S. G. S.	1,860
Peabody Mountain, Weston ...	U. S. G. S.	2,787
Peacham Corners	Aneroid	1,310

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Pearl, Grand Isle	U. S. G. S.	200
Pease Mountain, Charlotte	U. S. G. S.	700
Pensioners Pond, Charlestown	Beers	1,140
Perkinsville		Unknown
Peru, Village	U. S. G. S.	1,640
Petersburg Junction, Station	B. &. M. R. R.	467
Peth, Braintree		Unknown
Philadelphia Peak, Rochester	U. S. G. S.	3,168
Philo Mountain, Charlotte	U. S. G. S.	968
Pico Mountain	U. S. G. S.	3,967
Pico Pond, Sherburne	U. S. G. S.	2,220
Piermont, Station	U. S. G. S.	430
Piermont, a mile and a half s. w. near track	U. S. G. S.	438
Piermont, three miles s. w. of	U. S. G. S.	441
Pine Hill	U. S. G. S.	1,800
Pine Hill, Proctor	U. S. G. S.	1,445
Pinnacle, Bridgewater	U. S. G. S.	2,540
Pinnacle, Shoreham	U. S. G. S.	655
Pinnacle, Wells	U. S. G. S.	1,940
Pinney Hollow, Plymouth	U. S. G. S.	1,080
Pisgah Mountain, Westmore	Beers	3,800
Pittsfield, Brown School	U. S. G. S.	1,063
Pittsfield, River School	U. S. G. S.	810
Pittsfield, Village	U. S. G. S.	892
Pittsfield, White School	U. S. G. S.	884
Pittsford, Station	U. S. G. S.	370
Pittsford, Village	U. S. G. S.	540
Pittsford Mills	U. S. G. S.	540
Pittsford, Whipple Hollow	U. S. G. S.	600
Plainfield, Station	M. & W. R. R. R.	752
Pleasant Mountain	U. S. G. S.	800
Plymouth, Village	U. S. G. S.	1,420
Plymouth, Five Corners	U. S. G. S.	1,340
Plymouth Ponds	U. S. G. S.	1,395
Plymouth Union	U. S. G. S.	1,217
Podunk, West Hartford	U. S. G. S.	392
Pomfret, Village	U. S. G. S.	1,333
Pompanoosuc, Village	U. S. G. S.	400
Pompanoosuc, rail at station	U. S. G. S.	392
Pompanoosuc, 25 feet east of track three and a fourth miles southwest	U. S. G. S.	400

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Pompanoosuc, n. w. end of R. R. bridge third of a mile s. w.	U. S. G. S.	392
Pond Hill, Castleton	U. S. G. .S	1,150
Pond Mountain, Vernon	Beers	1,190
Post Mills, Thetford		Unknown
Potato Hill	Beers	3,986
Poultney, Village	U. S. G. S.	430
Poultney, East	U. S. G. S.	520
Poultney, Clark Hollow	U. S. G. S.	920
Poultney, Fennell Hollow	U. S. G. S.	660
Poultney, South	U. S. G. S.	560
Pownal, Station	U. S. G. S.	600
Pownal, Center, Church	U. S. G. S., B. M.	986
Pownal, Center, ¾ mile south	U. S. G. S.	1,095
Pownal, Methodist Church	U. S. G. S., B. M.	549
Pownal, Schoolhouse	U. S. G. S., B. M.	629
Pownal, Wrights Mill	U. S. G. S., B. M.	539
Preston Hill, Thetford	U. S. G. S.	1,480
Prindle Corners, Charlotte	U. S. G. S.	438
Pritchard Mountain, St. George	U. S. G. S.	1,140
Proctor, Marble Mills	U. S. G. S., B. M.	477
Proctor, Church	U. S. G. S.	560
Proctor, Hotel	U. S. G. S.	480
Proctor, Pine Hill	U. S. G. S.	1,445
Proctor Hill, Mt. Holly	U. S. G. S.	2,264
Proctorsville, Station	Rut. R. R.	928
Prospect Hill, Dummerston	U. S. G. S.	1,174
Prospect Hill, Westford	U. S. G. S.	1,046
Prospect Mountain	U. S. G. S.	2,690
Prosper, Woodstock	U. S. G. S.	
Pulpit Mountain, Guildford	U. S. G. S.	1,249
Pumpkin Hill, Tinmouth	St. J. & L. C. R. R.	986
Purchase Hill, Thetford	U. S. G. S.	2,544
Putnamville		Unknown
Putney, Station	B. & M. R. R.	251
Putney, Village at brook crossing	U. S. G. S.	320
Putney, East, Church	U. S. G. S.	327
Queen City Park	U. S. G. S.	150
Quechee	U. S. G. S.	600
Quimby Mountain, Sharon	U. S. G. S.	1,699
Ragged Hill, Bridgewater	U. S. G. S.	2,080
Randolph, Station	C. V. R. R.	691
Randolph Center		Unknown

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Ransomvale, Castleton	U. S. G. S.	700
Rattlesnake Point, Salisbury	U. S. G. S.	1,800
Rawsonville, Jamaica	U. S. G. S.	1,070
Raymond Hill, Bridgewater	U. S. G. S.	2,080
Ray Pond, Wilmington	U. S. G. S.	1,840
Reading, Village	U. S. G. S.	1,067
Reading, Hill School	U. S. G. S.	1,160
Reading Pond	U. S. G. S.	1,760
Reading, Bailey Mills	U. S. G. S.	1,077
Reading, Brown School	U. S. G. S.	1,742
Reading, a mile and one-fifth east of Brown School	U. S. G. S., B. M.	1,375
Readsboro, Village	U. S. G. S.	1,203
Readsboro, Falls	U. S. G. S.	1,660
Readsboro, Heartwellville	U. S. G. S.	1,800
Red Mountain, Arlington	U. S. G. S.	869
Red Rocks, Burlington	U. S. G. S.	160
Red Rock, Hinesburg	U. S. G. S.	1,600
Reid Hollow, Halifax	U. S. G. S.	1,200
Rhode Island Corners, Hinesburg	U. S. G. S.	767
Rice Hill, Dover	U. S. G. S.	2,947
Rices Mills, Thetford	U. S. G. S.	640
Richardson Hill, Strafford	U. S. G. S.	1,715
Richford, Missisquoi River	Aneroid	441
Richford, C. V. Station	C. V. R. R.	466
Richford, C. P. R. R. Station	C. P. R. R.	500
Richmond Hill, Bridgewater	U. S. G. S.	2,320
Richmond, Station	C. V. R. R.	321
Richmond, Universalist Church	U. S. G. S.	319
Richville, Shoreham	U. S. G. S.	340
Rickers Mills, Station	M. & W. R. R. R.	
Ripton, Village	U. S. G. S.	1,000
Ripton, Fisher School	U. S. G. S.	1,415
Ripton, Bridge over creek	U. S. G. S., B. M.	1,017
Riverside	C. V. R. R.	
Riverton, Station	C. V. R. R.	620
Roach Pond, Hubbardton	U. S. G. S.	537
Robinson Hill, Shrewsbury	U. S. G. S.	2,779
Robinson, Rochester	U. S. G. S.	1,004
Rochester, Branch School	U. S. G. S.	914
Rochester, Corner School	U. S. G. S.	1,085
Rochester, Jerusalem School	U. S. G. S.	1,600

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Rochester, Maple Hill School	U. S. G. S.	1,684
Rochester Mountain	U. S. G. S.	2,952
Rochester, North Hollow School	U. S. G. S.	1,483
Rochester, Randolph Gap	U. S. G. S.	2,353
Rochester, South Hollow School	U. S. G. S.	1,701
Rochester, Williams Mine	U. S. G. S.	1,961
Rochester, Village	U. S. G. S.	1,857
Rock Hill, Pawlet	U. S. G. S.	1,506
Rockingham	Rut. R. R.	357
Rockville, Starksboro	U. S. G. S.	535
Roger Hill, Mt. Holly	U. S. G. S.	1,640
Rogers Peak, Rochester	U. S. G. S.	2,200
Roods Pond, Milton	U. S. G. S.	376
Roman Mountain, Goshen	U. S. G. S.	3,020
Root Pond, Benson	U. S. G. S.	380
Round Hill, Shrewsbury	U. S. G. S.	1,680
Round Mountain, Brattleboro	U. S. G. S.	1,508
Round Mountain, Chittenden	U. S. G. S.	3,315
Roxbury, Station	C. V. R. R.	1,009
Royalton, Station	C. V. R. R.	510
Rupert, Village	U. S. G. S.	814
Rupert, Station, West	U. S. G. S.	709
Rupert, Clark Hollow	U. S. G. S.	940
Rupert, East	U. S. G. S.	840
Rupert Mountain	U. S. G. S.	1,860
Rutland, East Street and Jackson Ave.	U. S. G. S.	600
Rutland, Evergreen Cemetery	U. S. G. S.	540
Rutland, Main and Center Sts.	U. S. G. S.	625
Rutland, Killington Ave. and Stratton Road	U. S. G. S.	820
Rutland, Main and Cold River Road	U. S. G. S.	560
Rutland, South Main and Park, R. R. Crossing	U. S. G. S.	545
Rutland, Post Office	U. S. G. S.	600
Rutland, R. R. Station	U. S. G. S.	560
Rutland, Woodstock Ave. and Broad Street	U. S. G. S.	670
Ryegate, Station	B. & M. R. R.	464
Sable Mountain, Stockbridge	U. S. G. S.	2,690
Sadawga Pond, Whitingham	U. S. G. S.	1,660
Sage Hill, Jamaica	U. S. G. S.	2,140

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
St. Albans, Station	U. S. G. S., B. M.	385
St. Albans, Park, Bank and Church Sts.	U. S. G. S.	420
St. Albans, Fuller School	U. S. G. S.	180
St. Albans, French School	U. S. G. S.	1,019
St. Albans, School No. 8	U. S. G. S.	852
St. Albans, Lake and Main Sts.	U. S. G. S.	400
St. Albans, Smith and Congress Sts.	U. S. G. S.	600
St. Albans, Weeds Corners	U. S. G. S.	560
St. Albans Bay	U. S. G. S., B. M.	108
St. Albans Hill, Georgia	U. S. G. S.	900
St. Catherine, Lake	U. S. G. S.	477
St. Catherine, Mountain	U. S. G. S.	1,227
St. George	U. S. G. S.	500
St. Johnsbury, Station	St. J. & L. C. R. R.	556
St. Johnsbury, Athaeneum	Aneroid	660
St. Johnsbury, Court House	Aneroid	665
St. Johnsbury	Weather Bureau	711
St. Johnsbury Center	Aneroid	610
Salisbury, Station	U. S. G. S.	357
Salem Pond, Derby	Aneroid	1,000
Salisbury, half a mile east	U. S. G. S.	548
Salisbury, Village	U. S. G. S.	440
Salt Ash Mountain, Plymouth	U. S. G. S.	3,278
Sandgate	U. S. G. S.	800
Sargent Hill, Norwich	U. S. G. S.	1,240
Sargent Hill, Pawlet	U. S. G. S.	1,279
Saxon Hill, Essex	U. S. G. S.	820
Saxtons River, Village	U. S. G. S.	920
Scallop Mountain, Dorset	U. S. G. S.	2,380
Scott Pond, Charlotte	U. S. G. S.	260
Searsburg, Village	U. S. G. S.	1,700
Seaver Hill, Pomfret	U. S. G. S.	960
Seymour Lake, Morgan		Unknown
Shaftsbury, Village	U. S. G. S., B. M.	711
Shaftsbury, Center	U. S. G. S.	1,100
Shaftsbury, South	U. S. G. S.	737
Shaker Mountain, Starksboro	U. S. G. S.	1,920
Sharon, Station	C. V. R. R.	500
Shatterack Mountain, Jamaica	U. S. G. S.	1,940
Shatterack Mountain, Rupert	U. S. G. S.	2,376
Shaw Mountain, Benson	U. S. G. S.	664

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Sheffield		Unknown
Shelburne, Village	U. S. G. S., B. M.	174
Shelburne, Station	U. S. G. S.	160
Shelburne Falls	U. S. G. S.	206
Shelburne Pond	U. S. G. S.	329
Sheldon, Webster School	U. S. G. S.	340
Sheldon Junction, Station	St. J. & L. C. R. R.	346
Sheldon Springs, Station	C. V. R. R.	
Shellhouse Mountain, Ferrisburg	U. S. G. S.	680
Sherburne, Village	U. S. G. S.	1,260
Sherman, Whitingham	U. S. G. S.	1,100
Shoreham, Village, Hotel	U. S. G. S.	380
Shrewsbury, Village	U. S. G. S.	1,640
Shrewsbury, Cold River	U. S. G. S.	1,500
Shrewsbury, North	U. S. G. S.	1,760
Shrewsbury Peak	U. S. G. S.	3,737
Silent Cliff, Hancock	U. S. G. S.	2,460
Silver Lake, Barnard	U. S. G. S.	1,305
Silver Lake, Georgia	U. S. G. S.	783
Silver Lake, Leicester	U. S. G. S.	1,241
Simonds Hill, Pawlet	U. S. G. S.	1,240
Simonsville		Unknown
Sincho Corners		Unknown
Skeels Corner, Swanton	U. S. G. S.	320
Slack Hill, Plymouth	U. S. G. S.	2,120
Smith Peak, Shrewsbury	U. S. G. S.	3,226
Snake Mountain, Addison	U. S. G. S.	1,271
Sodom, Shaftsbury	U. S. G. S.	520
Somerset, Village	U. S. G. S.	2,000
South Barre	C. V. R. R.	
South Dorset	U. S. G. S.	980
South Duxbury		Unknown
South Fairlee, Station	B. & M. R. R.	430.68
South Franklin		Unknown
Southgate Mountain, Bridgewater	U. S. G. S.	1,720
South Halifax	U. S. G. S.	850
South Hero, Village	U. S. G. S.	140
South Hero, Iodine Springs House	U. S. G. S.	160
South Hero, Eagle Camp	U. S. G. S.	140
South Hill, Stockbridge	U. S. G. S.	2,000
South Hinesburg	U. S. G. S., B. M.	434

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
South Lincoln, ¾ mile west of village	U. S. G. S.	1,249
South Londonderry, Village	U. S. G. S.	980
South Lunenburg, Village	U. S. G. S.	1,180
South Mountain, Bristol	U. S. G. S.	2,387
South Newbury, Station	U. S. G. S.	407
South Newbury, bridge, mile s. w.	U. S. G. S.	400
South Newbury, two and a half miles southwest near track	U. S. G. S.	406
South Newfane	U. S. G. S.	680
South Peacham	Aneroid	1,000
South Pomfret	U. S. G. S., B. M.	738
South Pond, Marlboro	U. S. G. S.	1,620
South Poultney	U. S. G. S.	700
South Royalton, Station	C. V. R. R.	501
South Ryegate, Station	M. & W. R. R. R.	724
South Shaftsbury, Bridge	U. S. G. S., B. M.	711
South Shaftsbury, Town Hall	U. S. G. S., B. M.	754
South Shaftsbury, mile south	U. S. G. S.	788
South Starksboro	U. S. G. S.	1,098
South Strafford	U. S. G. S.	940
South Troy	Beers	749
South Vernon Junction	B. & M. R. R.	275
South Vernon Junction	U. S. G. S.	240
South Vershire	U. S. G. S.	1,550
South Walden	Aneroid	1,300
South Wallingford	U. S. G. S.	580
South Wardsboro	U. S. G. S.	1,600
South Whitingham	U. S. G. S.	1,580
South Windham	U. S. G. S.	
South Woodbury, Church	Aneroid	870
South Woodstock	U. S. G. S., B. M.	1,055
Spanktown	U. S. G. S.	590
Spaulding Hill, Poultney	U. S. G. S.	1,620
Spoon Mountain, Middletown	U. S. G. S.	2,030
Springfield, Fellows Shop	A. J. Crosby	630
Springfield, Mansion Hill	A. J. Crosby	683
Springfield, Jones and Lamson Lower Shop	A. J. Crosby	493
Springfield, Upper Main Street	A. J. Crosby	567
Springfield, Seminary Hill	A. J. Crosby	693
Spring Grove, Camp Grounds	U. S. G. S.	408

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Spruce Mountain, Arlington	U. S. G. S.	3,060
Spruce Knob, Poultney	U. S. G. S.	2,320
Spruce Pond, Orwell	U. S. G. S.	720
Spruce Top, Pawlet	U. S. G. S.	1,378
Stacy Mountain, Wardsboro	U. S. G. S.	1,935
Stamford, Village, Methodist Parsonage	U. S. G. S., B. M.	1,131
Stamford Pond	U. S. G. S.	2,620
Stannard		Unknown
Standing Pond, Sharon	U. S. G. S.	1,380
Starksboro, Village	U. S. G. S.	612
Starksboro, Rockville	U. S. G. S.	535
Sterling Mountain	Guyot	3,700
Stevens Mills	White	495
Stevens, Maidstone		Unknown
Stiles Mountain, Sudbury	U. S. G. S.	1,220
Stockbridge, Stony Brook School	U. S. G. S.	765
Stockbridge, Branch School	U. S. G. S., B. M.	750
Stockbridge, Station	U. S. G. S., B. M.	734
Stockbridge, Notown	U. S. G. S.	1,200
Stone Hill, Norwich	U. S. G. S.	1,680
Stowe, Village	Beers	700
Strafford, Village	U. S. G. S.	960
Stratton, Mountain	U. S. G. S.	3,859
Stratton Pond	U. S. G. S.	2,470
Stratton, Village	U. S. G. S.	1,860
Styles Peak, Peru	U. S. G. S.	3,404
Sucker Pond, Stamford	U. S. G. S.	2,240
Sudbury, n. e. corner, church	U. S. G. S.	572
Sugar Hill, Goshen	U. S. G. S.	2,091
Summit, Bennington County	Rut. R. R.	848
Summit, Chittenden County	C. V. R. R.	732
Summit, Groton	W. R. R. R.	1,388
Summit, Mt. Holly	U. S. G. S.	1,500
Summit, Warrens Gore	G. T. R. R.	1,377
Summit, Siding	C. P. R. R.	921
Summit, Station	C. P. R. R.	946
Sunderland	U. S. G. S.	649
Sunderland, Kelly Stand	U. S. G. S.	2,160
Sunderland, Chiselville	U. S. G. S.	760
Sunderland, McIntyre	U. S. G. S.	2,060
Sunderland, Lye Brook Meadows	U. S. G. S.	2,600

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Sunderland, Kansas	U. S. G. S.	840
Sunset Hill, Salisbury	U. S. G. S.	925
Sunset Lake, Benson	U. S. G. S.	503
Sutherland Falls	U. S. G. S.	500
Sutton, Summit	C. P. R. R.	1,377
Swanton, Village	U. S. G. S.	155
Swanton, Station	U. S. G. S.	137
Swanton, School No. 3	U. S. G. S.	416
Swanton, School No. 8	U. S. G. S.	183
Swanton Junction	U. S. G. S.	180
Tabor Mountain, Peru	U. S. G. S.	3,584
Tarbellville, Mt. Holly	U. S. G. S.	1,540
Tadmer Hill, Pawlet	U. S. G. S.	1,568
Taftsville, Woodstock	U. S. G. S., B. M.	668
Taftsville, three miles south, 40 feet south of schoolhouse ..	U. S. G. S.	954
Talcville, Rochester	U. S. G. S.	800
Terrible Mountain, Andover ..	U. S. G. S.	2,844
Texas Hill, Hinesburg	U. S. G. S.	1,560
The Ball, Arlington	U. S. G. S.	2,715
The Burning, Sunderland	U. S. G. S.	2,607
The Island, Weston	U. S. G. S.	1,220
The Ledge, Cornwall	U. S. G. S.	380
Thetford Center	U. S. G. S.	600
Thetford, Station	U. S. G. S.	408
Thetford, a mile and a half s. w.	U. S. G. S.	402
Thetford, Post Mills	U. S. G. S.	720
Thetford, Rices Mills	U. S. G. S.	580
Thetford, Union Village	U. S. G. S.	520
Thetford, Campbell Corner	U. S. G. S.	730
Thistle Hill, Pomfret	U. S. G. S.	2,000
Thompsons Point, Charlotte ...	U. S. G. S.	200
Thompsons Point, R. R. Station	U. S. G. S.	180
Thousand Acre Hill, Chittenden	U. S. G. S.	2,400
Thunder Head, Hancock	U. S. G. S.	1,240
Tice, Holland		Unknown
Tinmouth, Village	U. S. G. S.	1,263
Tinmouth Mountain	U. S. G. S.	2,847
Tinmouth Pond	U. S. G. S.	1,200
Tom Mountain, Plymouth	U. S. G. S.	2,040
Tom Mountain, Woodstock	U. S. G. S.	1,360
Topsham		Unknown
Town Hill, Pawlet	U. S. G. S.	1,319

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Town Hill, Poultney	U. S. G. S.	1,100
Townshend		Unknown
Troy	Aneroid	720
Trumbul Mountain, Shaftsbury.	U. S. G. S.	1,600
Tug Mountain, Thetford	U. S. G. S.	1,893
Tunbridge, Village	U. S. G. S.	640
Tunbridge, Whitney Hill	U. S. G. S.	1,260
Tunbridge, Williams Hill	U. S. G. S.	1,900
Tupper, Stockbridge	U. S. G. S.	860
Tyson		Unknown
Underhill Center		Unknown
Underhill Flats, Station	C. V. R. R.	707
Union Village, Thetford	U. S. G. S.	440
Vail Ridge, Pomfret	U. S. G. S.	1,440
Vergennes, Station	U. S. G. S., B. M.	203
Vergennes, Stevens House	U. S. G. S.	235
Vergennes, Bridge above Falls .	U. S. G. S.	140
Vernon	Weather Bureau	310
Vernon, Station	U. S. G. S.	280
Vernon Center, Church	U. S. G. S.	290
Vernon, Village	U. S. G. S.	270
Vershire, Center	U. S. G. S.	1,680
Vershire, Mill Village	U. S. G. S.	1,140
Vershire, Copperfield	U. S. G. S.	940
Victory		Unknown
Waitsfield	Aneroid	720
Waits River		Unknown
Walden, R. R. Station	St. J. & L. C. R. R.	1,656
Walden, one mile west road to S. Walden	Aneroid	1,840
Wallace Ledge, Castleton	U. S. G. S.	1,060
Wallingford, Village	U. S. G. S.	580
Wallingford, East, Station	U. S. G. S.	1,220
Wallingford, South	U. S. G. S.	620
Wallingford Road	U. S. G. S.	2,157
Wallispond, Canaan		Unknown
Walnut Hill, Danby	U. S. G. S.	1,546
Wantastiquet Mountain	U. S. G. S.	1,384
Wardsboro, Village	U. S. G. S.	980
Wardsboro, Bucketville	U. S. G. S.	1,100
Wardsboro, South	U. S. G. S.	1,600
Wardsboro, West	U. S. G. S.	1,260
Warren, Hotel	Aneroid	912

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
Washington		Unknown
Waterbury	C. V. R. R.	427
Waterbury Center		Unknown
Waterford		Unknown
Waterville		Unknown
Weathersfield		Unknown
Websterville, Barre		Unknown
Wells, Village	U. S. G. S.	502
Wells, East	U. S. G. S.	1,080
Wells River Pond, Groton	Beers	1,900
Wells River, Station	M. & W. R. R. R.	435
Wells River, top of bolt in base of Signal 402	B. & M. R. R.	446.47
Wells River, Hales Tavern	Aneroid	395
Wenlock, Station	G. T. R. R.	1,149
West Addison	U. S. G. S.	100
West Barnet		Unknown
West Berkshire		Unknown
West Berlin		Unknown
West Bolton		Unknown
West Brattleboro, Cong. Church	U. S. G. S., B. M.	443
West Bridgewater	U. S. G. S., B. M.	1,058
West Burke, Station	B. & M. R. R.	9,324
West Castleton	U. S. G. S.	500
West Charlestown	Aneroid	1,050
West Chesterfield, Church	U. S. G. S., B. M.	403
West Concord, Station	St. J. & L. C. R. R.	876
West Corinth		Unknown
West Cornwall	U. S. G. S.	460
West Danville, Station	St. J. & L. C. R. R.	1,496
West Derby	Aneroid	765
West Dover, Church	U. S. G. S.	1,714
West Dummerston, Church	U. S. G. S.	391
West Fairlee, Village	U. S. G. S.	760
Westfield	Aneroid	720
Westford Center	U. S. G. S., B. M.	467
Westford, Brookside School	U. S. G. S.	510
Westford, Bowmans Corners	U. S. G. S.	740
Westford, King School	U. S. G. S.	870
Westford Pond	U. S. G. S.	790
West Glover		Unknown
West Halifax	U. S. G. S.	1,180

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
West Hartford, 50 feet north of station	U. S. G. S.	420.5
West Hartford, 3.7 miles south in brick schoolhouse in Hartland	U. S. G. S.	941.9
West Hartford, 6 miles south in foundation of farmhouse	U. S. G. S.	631
West Haven	U. S. G. S.	380
West Jamaica	U. S. G. S.	1,540
West Lincoln, north end of iron bridge	U. S. G. S.	890
West Marlboro	U. S. G. S.	1,760
West Milton	U. S. G. S.	114
Westminster, Station	B. & M. R. R.	256
Westminster, West		Unknown
West Mountain, Shaftsbury	U. S. G. S.	2,022
Westmore		Unknown
West Newbury		Unknown
West Norwich	U. S. G. S.	1,120
Weston, Village	U. S. G. S.	1,300
West Pawlet	U. S. G. S.	480
West Rupert, Village	U. S. G. S.	760
West Rupert, Station	U. S. G. S.	709
West Rutland, Station	U. S. G. S.	500
West Salisbury	U. S. G. S., B. M.	420
West Swanton	U. S. G. S.	108
West Topsham		Unknown
Westville, Groton		Unknown
West Townshend		Unknown
West Wardsboro	U. S. G. S.	1,340
West Windsor, Ralph School	U. S. G. S.	1,240
West Woodstock	U. S. G. S.	713
Weybridge	U. S. G. S.	160
Weybridge Center	U. S. G. S.	420
Whetstone Bluff, Sunderland	U. S. G. S.	2,200
Wheelock		Unknown
Whipple Hollow, Pittsford	U. S. G. S.	600
Whitcomb Hill, Strafford	U. S. G. S.	1,859
White Creek, Station	U. S. G. S.	660
White Hill, Dover	U. S. G. S.	2,702
White Hill, Hillsdale	U. S. G. S.	1,713
Whites Hill, Wardsboro	U. S. G. S.	2,702

ELEVATIONS IN VERMONT—(*Continued*).

Locality.	Authority.	Elevation. Feet.
White River Junction, Catholic Church	U. S. G. S., B. M.	367.5
White River Junction, Fairview Terrace	U. S. G. S.	440
White River Junction, Second Terrace	U. S. G. S.	500
White River Junction, Bridge over White River to Hartford	U. S. G. S.	340
White River Junction, Station tracks	U. S. G. S.	340
White Rocks Mountain, Goshen	U. S. G. S.	3,307
White Rocks, Wallingford	U. S. G. S.	2,662
Whiting	U. S. G. S.	391
Whitingham, Village	U. S. G. S.	1,600
Whitney Hill, Tunbridge	U. S. G. S.	1,440
Whitney Mountain, Marlboro	Beers	2,347
Wickopee Hill, Dummerston	U. S. G. S.	1,650
Wilcox Hill, Benson	U. S. G. S.	688
Wilcox Hill, Shrewsbury	U. S. G. S.	2,072
Wilcox Peak, Pittsfield	U. S. G. S.	2,921
Wilder, front of station	U. S. G. S.	4,087
Wilder, top of sill, side door, Library	U. S. G. S., B. M.	430
Williams Hill, Tunbridge	U. S. G. S.	1,940
Williamstown, Station	C. V. R. R.	968
Williamsville, Church	U. S. G. S., B. M.	560
Williamsville, Station	U. S. G. S.	400
Williston, M. E. Church	U. S. G. S.	500.5
Williston, top of Muddy Brook Hill	U. S. G. S.	308
Willoughby Lake	Beers	1,162
Willoughby Mountain	Beers	2,654
Wilson Hill, Brandon	U. S. G. S.	688
Wilmington, Baptist Church	U. S. G. S., B. M.	1,548
Winhall	U. S. G. S.	1,200
Winhall, Bondville	U. S. G. S.	1,200
Windham		Unknown
Windsor, Methodist Church	U. S. G. S., B. M.	354
Windsor, Old Cemetery	Aneroid	360
Windsor, Band Stand in Park	Aneroid	380
Windsor, Main St. & Depot Ave.	Aneroid	350
Windsor, Station Platform	Aneroid	325

ELEVATIONS IN VERMONT—(*Concluded*).

Locality.	Authority.	Elevation. Feet.
Windsor, Track in front of Station	B. & M. R. R.	321
Winooski, Station	U. S. G. S.	200
Winooski, end of bridge	U. S. G. S.	136
Winooski, River below lower falls	U. S. G. S.	107
Wolcott, Station	B. & M. R. R.	720
Wolcott, Town Hall	Aneroid	1,200
Woodbury Center	Aneroid	
Woodford, near church	U. S. G. S., B. M.	2,215
Woodford, 2 miles east, 160 feet from small bridge on boulder	U. S. G. S., B. M.	2,319.5
Woodford Hollow, Camp Comfort	U. S. G. S.	1,266.8
Woodford, opposite power house	U. S. G. S.	1,671.7
Woodford, five miles east, top of hill	U. S. G. S.	2,267.7
Woodlawn Mountain, Danby	U. S. G. S.	3,072
Woodstock	U. S. G. S., B. M.	705
Woodstock, Curtis Hollow School	U. S. G. S.	1,166
Woodstock, Fletcher School	U. S. G. S.	1,340
Woodstock, Pelton School	U. S. G. S.	1,092
Woodstock, Walker School	U. S. G. S.	1,700
Worcester		Unknown
Worth Mountain, Hancock	U. S. G. S.	3,500
Wrightsville, Montpelier		Unknown
Yantz Hill, Richmond	U. S. G. S.	1,060
Zion Hill, Hubbardton	U. S. G. S.	1,229

COPPER MINING IN VERMONT.

E. C. Jacobs.
University of Vermont.

There was a time, before the opening of the Lake Superior deposits, when Vermont possessed in the Ely mine the largest copper property in the country. Since then copper production in this State has experienced many vicissitudes and practically no copper has been made since 1907. Still, development work and experimentation with different methods for concentrating and smelting the ores have gone on intermittently and now the prospects are bright for Vermont to resume her place among the copper producing states. A brief survey of the situation should therefore prove of interest.

Copper in Vermont occurs in the form of chalcopyrite ($CuFeS_2$), associated with pyrrhotite (Fe_7S_8), and these minerals form a series of lenses of pods, similiar to the talc and serpentine deposits. Also like these deposits, the copper-containing lenses form a chain which lies in and conforms to the foliations of the country (Bradford) schists. This chain lies in the eastern part of Orange County a few miles west of the Connecticut River and extends in a northerly and southerly direction for a distance of twenty miles. Its extension into Canada is found at the Capleton mines of Quebec. There are three groups of mines, in Orange County: the Foster (or Cleveland) and Elizabeth mines, at South Strafford; the Vershire (or Ely) mine, in southeastern Vershire, (Copperfield); and the Union, Cuprum, and Eureka (Pike Hill) mines, in the northern part of Corinth. Of these, the Elizabeth and Pike Hill properties are expected to become producers again in a short time.

THE ELIZABETH MINE.

This, together with the old Foster mine adjoining it, is the oldest of the Vermont copper properties. Geologically, it consists of a series of elongated lenses, or flattened pods, of mineral, "en echelon," lying in the west side of a valley, one and one-half miles from South Strafford and ten miles from Pompanoosuc (Boston and Maine railroad station). The lenses have a strike

of north 20 degrees east, a dip of about 60 degrees easterly, and a pitch of 12 to 14 degrees, downward to the north. The lenses vary greatly in thickness, the maximum reported being 100 feet, while the average is 12 to 18 feet. Mining began on the south end of the lode, at the old Foster or Cleveland mine, and the old workings show a length on the outcrop of some 1,200 feet, a maximum width between foot and hanging wall of 20 feet, and a depth of 200 feet. A large part of the mining, near the surface, was done by open cutting.

Immediately north of these workings and practically a continuation of them, is the Elizabeth mine, which appears to be on an independent lens of mineral, at least 1,200 feet long, and plunging downward into the earth at an angle of about 14 degrees. The upper levels of this mine have been worked out. A tunnel, or adit, has been driven horizontally into the hill for a distance of 1,350 feet, to meet the present working level. North of the junction, an inclined shaft has been sunk to the present working faces of the ore. This is now full of water and a great deal of pumping will have to be done in order to resume mining operations.

The ore forming these lenses consists of chalcopyrite disseminated, for the most part, in pyrrhotite. There is also some occurrence of pyrite and sphalerite and gangue minerals (sericite, biotite, quartz, and garnet) in the ore, which closely resembles that at Ducktown, Tenn. This Ducktown material is being successfully treated for both copper and sulphur. The pyrrhotite of the Vermont mines is almost non-magnetic, so that magnetic concentrating devices have not been generally successful.

During the past seven years extensive prospecting work has been carried on by means of diamond drilling, in order to gain as accurate information as possible of the amount of ore available. Twenty-five holes have been drilled, representing over 9,000 feet of borings, and all but three of these have been sunk from the surface. Based on the evidence of these drill cores, it has been estimated that there are at present some 600,000 tons of ore "in sight," while Mr. Frank L. Nason, geologist, argues that the drilling has also indicated the presence of a new lens, north of the Elizabeth ore body, which, if it persists to a depth (on the pitch of the lens) of 4,000 feet, should yield an equal amount of ore.

This group of mines has been examined by many eminent geologists and metallurgists and they agree that there is a colossal ore body which awaits only the proper mining and metallurgical treatment to yield a profitable return. The mine has been extensively sampled and, based on the analyses of these samples, the following estimates of average richness in copper have been submitted:

1890, Henry M. Howe	3.65%
1899, A. R. Ledoux	3.35%
1902, A. W. Petre	2.63%
1903, W. H. Weed	3.25%
1904, O. Sussmann	3.53%
1906, Ricketts & Banks	2.50%

The ore also carries about two-tenths of an ounce of silver and a trace of gold.

The average composition of many mine samples is given by the following analysis:

Copper	2.40%
Iron	38.38%
Silica	24.11%
Sulphur	24.27%
Alumina	6.40%
Lime	1.20%
Magnesia	.80%
Alkalies	2.00%
Ti, P, Ni, etc.	.50%
	100.06%

Economically, the old Foster or Cleveland mine was opened in 1793 and worked for years as a source of copperas, or ferrous sulphate, no attention apparently being paid to its copper content. But in 1830 copper smelting was begun, the ore being roasted in stalls and then reduced in a small reverberatory furnace. The mine was operated intermittently till 1883, at times as many as 300 men being employed. In this year the Elizabeth Copper Company was formed, controlled by the Tyson family, of Baltimore, and operations were begun on a larger scale. A new water jacketed blast furnace, with a capacity of 40 tons of matte a day (said to be the first of this type erected in the United States) was built and the ore, after being roasted free of its superfluous sulphur, was smelted to a 40% matte (matte is a double sulphide of iron and copper, $Cu_2S.FeS$). This material was then roasted and smelted to "black copper," which was presumably sent to the refinery.

A new smelting plant, consisting of a 150 ton blast furnace, a 40 ton matting furnace, and a 10 ton "blister copper" furnace was put into commission in 1901. This plant was run till the end of the year when, due to the falling price of copper, it was closed. The old process of heap roasting was very wasteful and expensive. The property lay idle till the spring of 1905, when a plant for the magnetic separation of the pyrrhotite from the chalcopyrite was built, the idea being to get rid of the iron sulphide and so be able to smelt the remaining copper mineral to a rich matte. But the pyrrhotite of this region possesses little magnetism and the process, after being tested for about a year, was given up and the mine was once more closed.

Plans for the erection of a more modern reducing plant, which should smelt the raw ore pyritically (that is, make use of the large amount of sulphur in the ore as a partial source of fuel) were prepared in 1907 and the new plant was completed in November, '08, when the furnace was put in blast. At the same time the old plant was operated on heap roasted ore and some 700 tons of 16% copper matte were produced and marketed. The new plant was run intermittently till February, '09, when it was destroyed by fire. Experimental work was carried on till November, '09, when the main flue collapsed, due to an explosion, and operations were discontinued.

Recently the Elizabeth property and the old Foster mine have been consolidated into the Vermont Copper Company, of Delaware, with Mr. August Heckscher, president, Prof. Geo. A. Guess, consulting metallurgist, and Mr. N. O. Lawson, mining engineer. The company owns 1018 acres in fee and 160 acres of mineral rights, covering possible extensions of the ore body along its strike. Experimental smelting has seemed to show the practicability of smelting the raw ore pyritically and a three months run is now under way, making use of a 300 ton water jacket furnace with large blower capacity. It is said that former attempts to smelt pyritically were unsuccessful owing to the large amount of alumina in the gangue of the ore. Proper fluxing has, it is claimed, overcome this difficulty and prospects for the future are bright. The raw ore is to be smelted to a first matte, carrying eight to ten percent of copper, which will be resmelted to a second matte rich enough to be shipped to the refinery. A charter for an extension of the Central Vermont Railroad from the mine to Sharon, eight miles away, has been obtained. Electric power is brought from the same place.

VERSHIRE.

Six miles north of the South Strafford deposits and in line with their strike are the remains of Vermont's most celebrated copper mine, the Ely. This mine, in the town of Vershire, consists of a series of mineral lenses, *en echelon,* striking about north and south, dipping 24 degrees to the eastward and pitching about 26 degrees northerly. Reports of the depth of the mine, along the strike, vary from 2,300 to 4,00 feet.

As at the other deposits, the ore consists of chalcopyrite and pyrrhotite together with some pyrite and sphalerite. In the old days it appears to have been considerably richer than that at the Elizabeth, hand picked material running as high as seventeen percent copper. From studies of thin sections of the ore, Mr. W. H. Weed[1] has brought out the interesting fact that the sulphides are of later formation than the country schists in which they lie; while of the sulphides, "the chalcopyrite is partly of the same age as the pyrrhotite, but the larger masses of this mineral fill fractures in the pyrrhotite and represent the filling of later fractures."

Regarding the history of this famous mine, Weed states that, "it was discovered in 1821, the burnt appearance of the outcrop leading to digging by the neighboring farmers. The discoverers organized the Farmers' Company, opened up a body of good ore, and smelted it in a rude furnace. This was continued with more or less success and interruption until in 1853 the Vermont Copper Mining Company acquired the property, completed an adit, and opened up an ore body 8 to 16 feet in thickness that averaged over 9% copper, as shipped, some shipments yielding as much as 17%."

The workings were at one time called the Pollard mine, but they were later acquired by Smith Ely, under whom they achieved their greatest productivity. Many stories are still told of the palmy days of the Ely mine: of the great prosperity of the town; of the Legislature's changing its name from Vershire to Ely, in 1880; later, of the Ely War, when State troops were called out to quell the rioting of the miners, whose wages were greatly in arrears when the ore gave out; of the town's name being changed back to Vershire by a subsequent legislature, etc. The mine was in the heyday of its prosperity about 1882 when, it is said, Mr. Ely was offered $1,250,000 for the property; but early in the following year, on account of the increasing leanness of the ore and probably of bad management, the fortunes of the company waned and the crash came in July, 1883.

After this Weed states that the mine was successfully and profitably worked, clearing over $4,000 a month in 1888 but that, in the following year, further litigation led to a change of ownership. On the other hand, a local authority claims that the property, during this time, was in the charge of Judge of Probate S. M. Gleason, presumably acting as receiver.

At any rate, in 1889, a Mr. Krause, of New York City, bought the property for $36,000 and started to rehabilitate it. The plant was remodeled and a 100-ton concentrator built, at a cost of $53,000. In spite of large investments nothing came of his attempts and the plant remained idle till 1900. In this year Mr. George Westinghouse bought it and expended a very large amount of money in unwatering the old workings and experimenting with new methods of treatment. His efforts were disappointing, while, it is said, over zealous tax assessors imposed severe burdens on the company.

[1] Bull. U. S. G. S. 225, p. 195.

The result was that the mine was not only closed down but the plant was demolished and "junked," the miner's houses were removed or torn down, and the village of Copperfield, as it was called, ceased to exist. There are still those who claim that much ore still remains in these workings and that the mine was never "bottomed," but in all probability, the property will never be reopened.

CORINTH.

The third group of copper mines on this belt is located in North Corinth, eleven miles north of the Ely and in line with it. This group includes the old Union mine, which has not been active since 1889, the Cuprum, and the Eureka mine, all located on Pike Hill.

The country rock is a quartz-mica schist and the ore lenses lie in it concordantly, with a strike of north, six degrees east, a dip of 28 to 30 degrees easterly, and a pitch of 60 degrees. The ore lenses vary from 6 to 60 feet in width (average is 10 feet), up to 400 feet in length, and as far as known 200 feet in the third dimension. The mineral is chalcopyrite and it occurs not only disseminated in the pyrrhotite but also in considerable masses of pure mineral, so that hand picking is easily practiced. The ore appears to merge into the country rock to some extent, for biotite and some contact minerals are found enclosed in it.

Copper was discovered at some time previous to 1850. The property was purchased in 1854 by a New York firm which started development work. The Union Mining Company was incorporated in 1865 and mining operations were begun on what was then a fairly large scale. Weed states that the production from 1866 to 1881, inclusive, amounted to 31,504 tons of ore, which carried from 8.5 to 10 percent of copper. The property was acquired in 1878 by Smith Ely, who shipped the ore to Copperfield for smelting. In 1879 and 1880, according to Weed, a total of 5,712,604 pounds of "fines" carrying 2.7 to 4.5 percent copper, were shipped to the Copperfield smelter. In 1879 the Vermont Copper Company was organized by the same interests and mining and shipping were continued till 1889.

Weed states that: "The property is developed by an inclined shaft about 900 feet long, or 766 feet below the adit level. Down to a depth of 300 feet four overlapping lenses of ore were worked. ***Assay of a sample of selected ore from the dump showed 8.15% copper, 25% silica, with a trace of gold and 0.3 ounce of silver per ton. The vein has a north-south course, dips 30 degrees east, and has an average thickness of 8 feet."

The Cuprum and Eureka lodes lie south of the Union, the Cuprum near the summit of Pike Hill. Nothing seems to be known about the beginning of the Cuprum but in 1860 it was taken over by the Corinth Copper Company, which sunk an inclined shaft in the ore body and stoped north and south. An adit, 1,000 feet long was driven on a lower level to intercept the lode and this, when found, was called the Eureka mine. The adit met the upper (Cuprum) lens near its lower end where it was "pinching out" and, this not proving particularly encouraging, very little work was done on it, chief attention being given to the thicker part of the lens. This was worked intermittently till 1889. The ore was washed and hand picked.

In 1904 Knox and Allen, mining engineers of New York City, acquired the property for private interests and started further development work. This showed that there was another lens lying in line with the strike of the Cuprum but offset below it by a distance of 20 feet. A shaft sunk from the junction of the adit and ore body, in this new lens opened up a body of exceptionally high grade ore. The combined length of the two lenses, on the pitch line, proved to be some 900 feet, while below the second lens a third pod was discovered on which the company is now at work. Mining operations were started on a larger scale in both the Cuprum and Eureka mines. The high grade ore was hand sorted and shipped to New York smelters, while the lower grade material was stored on the dumps for future mill treatment.

In 1905 the Pike Hill Mines was incorporated and took over the property. Mr. John H. Allen, of the firm of Knox and Allen, is president. Knox and Allen designed and erected a magnetic concentrating plant, using Wetherill separators, which started in April, 1906 and ran continuously until November, 1907, when the price of copper falling, the mill was closed.

Since August, 1905, the company has been experimenting with the Wood floatation process for the concentration of its copper mineral. This method, unlike the oil floatation processes which have come into such extensive use during the last few years, makes use of water, only, as the medium by which the separation of minerals is effected. The ore, ground to 40 mesh size and thoroughly dried, is showered upon the surface of water contained in an oblong box, having a longitudinal partition extending to the bottom. The side walls of the box converge to this partition, near the bottom, assuming a V-shaped cross section (like a "spitzkasten"). Near one edge of the box the ore strikes the surface, where fine jets of water, playing horizontally below it, produce a fast moving film which carries the ore forward towards an endless felt belt, working across the central partition. The pyrrhotite and gangue material fall through this film to the bottom of the tank; while the chalcopyrite, floating on the film, is carried to the belt, which lifts it across the partition and drops it

into the water on the other side. The chalcopyrite, being now wet, sinks to the bottom. Spigots discharge both heads and tails from the bottom of the machine. The heads are then dried and bagged for shipment to the smelter. The process appears to be best explained as a surface tension phenomenon, the pyrrhotite and gangue minerals being at once wetted and sinking, while the chalcopyrite is not wetted and so floats and is carried forward to the belt.

The experimental runs have been so satisfactory that the company has decided to install this type of machine. The clean tailings made by this process and the economies gained by not smelting the ore at a place remote from fuel, fluxes, etc., should all count strongly towards the success of the enterprise.

The writer is indebted to Mr. Harry G. Hunter, manager of the company, for much of the above information.

OTHER COPPER MINES.

At Wolcott there is a considerable deposit of copper bearing pyrrhotite on which but little work has been done. Mineral Resources of the United States for 1885 gives the analysis of this ore as follows:

Sulphur	34.4 %
Iron	32.7 %
Copper	3.27%
Silica, etc.	29.50%
	99.87%

In Berkshire there is said to be a large deposit of chalcopyrite and bornite. The Vermont and Boston Mining Company was at one time at work on this deposit, sinking a shaft 100 feet and drifting 85 feet. Some thesis work, done at the Massachusetts Institute of Technology, showed the ore to carry 1.42% copper. This was obviously too low for profitable working, in this region at least.

Some small pockets of chalcopyrite were found in the grit talc at the Greeley mine, Stockbridge, a few years ago, and minute portions of copper pyrite occur in Middlebury and Brandon, but these have no commercial significance.

THE GEOLOGY OF WESTERN VERMONT.

G. H. PERKINS.

The main object of the following pages is to give such a general and, so far as possible, comprehensive account of the geological formations which are manifested by outcrops in the different towns west of the Green Mountains that a geologically inclined visitor may be guided in his studies. And also it is hoped that from the information given anyone desiring to know the geology of one or another of our lake towns may find here at least some of the facts he needs.

The survey is extending its work over the whole State as far as the resources at its command will allow, but under present conditions the progress is slow, both because the funds provided are too small to allow other than a very small force of investigators and because the character of a large part of the rocks of Vermont is such as to make it often very difficult to reach definite conclusions.

The geology of the Champlain Valley is for the most part less complicated than that part of Vermont lying east of this area and has been more successfully studied. For this reason the region included in this paper is limited to those towns which are on the eastern side of Lake Champlain and west of the Green Mountains.

Through the explorations of Professor C. H. Richardson large additions have been made to our knowledge of eastern Vermont and it is expected that he will continue his work for years to come. As Professor Richardson's paper in this Report shows, he has been very successful in his work especially during the past season.

Dr. C. H. Hitchcock, now of Honolulu, in recent years has done considerable investigating in the area covered by the Strafford, Hanover and Woodstock Quadrangles and farther south. Professor C. E. Gordon has worked in the Bennington Quadrangle. Professor Jacobs has worked on the Talc and Serpentine deposits and others have taken up some limited areas, but a great deal of work remains to be done in a large part of Vermont before accurate and full details of the geology can be given. Nor has all needed investigation been carried on even in those parts of the State that are best known.

As has been indicated, this paper does not include any part of Vermont except the narrow region between the Green Mountains and Lake Champlain and deals mostly with what are known as The Lake Towns. In this area are comprised nearly all the unmetamorphosed stratified beds found in the State for one cannot go far from the lake eastward before he finds the rock changing, often suddenly, from limestone or shale to the schist and gneiss of the Green Mountain mass.

Conversely, as one approaches the lake he finds the rocks, in many places at least, growing more and more regular and near the lake limestones, sandstone and shale with well defined fossils and the entire shore from Canada to Whitehall is formed of these rocks, except where bays have been cut out and faulting has occurred and then there is sand.

From this it follows that if a geologist wishes to collect fossils in Vermont his best opportunity will be along or near the lake shore. But nowhere is there a great variety in the formations for the entire range is only from the Lower Cambrian to the Utica, including the latter. There is a small exception to this in the lignite of Brandon which will be noticed later, and of course, the great display of Pleistocene which is seen everywhere in the State.

THE CAMBRIAN.

The upper beds of the Lower Cambrian are well displayed, but only very little of the Middle and Upper Cambrian, and all the principal terranes of the Ordovician from Beekmantown to Utica.

All these occur in long, narrow, north and south exposures which follow the trend of the Champlain Valley. With the exception of the Utica the various beds along the lake do not appear to have been greatly tilted or disturbed. There are numerous anticlines and a few synclines in the limestones and sandstones, but they are mostly small and in general the dip, most often to the east, is but a few degrees.

Naturally, where there has been faulting, and such places are not infrequent, there has been tilting, crushing and other disturbance, but for the most part these conditions are very limited in extent, even where dikes have been formed.

As one approaches the mountains an entire change in the rocks appears, often only a few miles east from the lake. Instead of stratified limestone, shale and sandstone, all the rocks are greatly crushed, crumbled and otherwise disturbed, schist and gneiss.

From the Canada line south through the State the Cambrian appear mostly as a highly silicious, red sandrock of varying shades, the dark prevailing, though in places the range is very great and even white quartzite may occur. The greater part however is a dark red.

At Swanton, St. Albans, and Burlington there are small masses that formed in deeper water, contain much more lime and are often greatly brecciated. These are quarried and worked as "Champlain Marble" a very fine and beautiful stone used all over the country. The coloring is mostly red of different shades and white. While the red sandrock forms the bulk of the Cambrian in Vermont, there is a good deal of gray quartzite, some dark gray silicious limestone and dark, hard shales, as the famous Parker Ledge. In the northern part of the lake many of the headlands and cliffs on shore are of the sandrock.

Coming into the State from Canada on the north, the red sandrock extends south as a narrow strip for about thirty miles and is the rock at the lake shore from St. Albans Bay to Shelburne Bay with the exception of Colchester and Appletree points which are Utica. Somewhat east from the lake not far from the north line of Charlotte the outcrop becomes very much wider and continues through Monkton where it occupies most of the town, on through Ferrisburg south suddenly becoming very narrow and so continuing to the extreme northern part of Orwell where it stops.

Most of the hills between the Green Mountains and Lake Champlain are of this rock, as Cobble Hill in Milton, Red Rocks at Burlington, Mount Philo and Snake Mountain.

By far the greater part of our Cambrian is quite destitute of fossils, at any rate they have not been found, but some layers are very well filled. Many of the species have been described and figured in the Tenth Annual Report, U. S. G. S. and in numerous later papers by Doctor Walcott.

The longer I study the Cambrian of this region the more fully I am convinced that in some of the beds this absence of fossils is apparent rather than real for there are numerous layers in which abundant casts, etc. are readily seen on weathered edges, while in the solid rock they are wholly invisible and the rock would therefore be set down as unfossiliferous were there no weathering to reveal the hidden forms.

How much of the whole series of Cambrian beds are thus cryptically fossiliferous it is of course impossible to know, but some of them are certainly of this sort. It is however, probable that fossils are few in the great mass of these beds.

What fossils there are are mostly casts and it is noticeable that in many beds there are few or perhaps only one species present in one layer or several adjacent, while in another layer a different set of species occurs.

Again only one part of an animal is found as for example, in some layers of gray quartzite in Colchester the glabellas of Olenellus are very abundant and distinct, but no other part of the species can be found and no other species. Elsewhere Ptychoparia alone occurs and so on. In the gray limestone where Kutorgina, Iphidea, etc. are found a larger number of species

occur. In many layers in which little except worm borings, sun cracks, ripple marks are common few or no fossils are to be seen. These evidences of shallow water formation are found throughout the Cambrian of this region.

The thickness of the Cambrian in Western Vermont has not been ascertained, but it must be some thousands of feet in all.

THE BEEKMANTOWN LIMESTONE.

The rocks of this formation extend from Northeastern Milton south through the different towns the exposure gradually increasing in width until it reaches the middle of Hinesburg when the mass suddenly narrows to a mere band and thus it continues as far as the north line of Monkton. This great belt is composed of a gray limestone usually very silicious, but in places less so and highly calcareous so that it makes excellent lime, as at the Lime Kilns east of Winooski.

This great belt of limestone seems almost wholly destitute of fossils so that its age cannot be certainly determined throughout its entire extent and it is possible that a part of it is of Cambrian age, but north of the Lime Kilns in Colchester, Mr. Griffin has found very good specimens of Pleurotomaria and Cryptozoon which are undoubtedly Beekmantown and I think that the whole mass from north to south is of this age and that sooner or later fossils will be found that show this.

From the north line of Monkton south for several miles none of this limestone appears, but in the eastern part of this town about midway between the north and south border it reappears in force and there is a wide band for some miles when it is greatly narrowed to continue through Vermont into Massachusetts.

Whether this southern portion is of the same age as the northern I do not know as I have had no opportunity to examine it, but apparently some of it is if not all.

In the 1861 Vermont Geological Report a mass of this limestone is called "Aeolian." It is not necessary to bring up here the long disputed question of the age of this Aeolian limestone which has long since been settled by subdivision of the original group of rocks and abandonment of the name. About all the recognized divisions of the Ordovician appear to have been included in Aeolian.

Whether the large mass of rock mentioned shall prove to be all Beekmantown or not it is certain that there is in the more western outcrops abundant limestone that is unquestionably Beekmantown. Some of this forms cliffs along the shore of the lake, some is inland. These are nowhere contiguous to the belt just mentioned, but are separated from it by later rocks.

Reference to some of the towns in the accounts which follow will show where the Beekmantown is to be found in any considerable amount.

The most famous of these localities is that at Fort Cassin at the mouth of Otter Creek. At this place there was evidently in Beekmantown time some cove into which currents washed the remains of cephalopods, trilobites, mollusca, etc. so that a very interesting assemblage of animal forms was collected in a small area and exceedingly well preserved for the most part.

Many fine specimens collected at Fort Cassin by Drs. Brainerd, Seely and the writer were sent to Dr. Whitfield of the American Museum of Natural History, N. Y., and described by him in Bulletins, vol. I, pp. 293-348, plates XXIV-XXXIV, vol. II, pp. 41-65, plates VII-XIII, vol. IX, pp. 177-184, plates IV-V. Some of these plates are also reproduced in the Seventh Report of this series, page 313 and the interested reader is referred to these. In all, more than sixty species, most of them new, have been found at this locality.

Unfortunately it is not now a good collecting ground as most of the fossils which can be gotten from the hard limestone have been carried away and the property has passed into the control of a company which has erected a club house there and not unnaturally object to further breaking the rocks.

Originally there was an oak grove over much of the place and the soil covering the limestone ledge was so filled with the vegetable acids that it decomposed the stone enclosing the large cephalopods and they were many of them in this way beautifully separated so that some of our best specimens were not broken from the rock, but simply picked out from the vegetable mold on top.

Of course such an opportunity comes very seldom and is soon exhausted. But aside from the above condition, the mass of solid limestone does not appear to have been very rich except in a limited area. On Providence Island and on Valcour similar species and many of the same have been found.

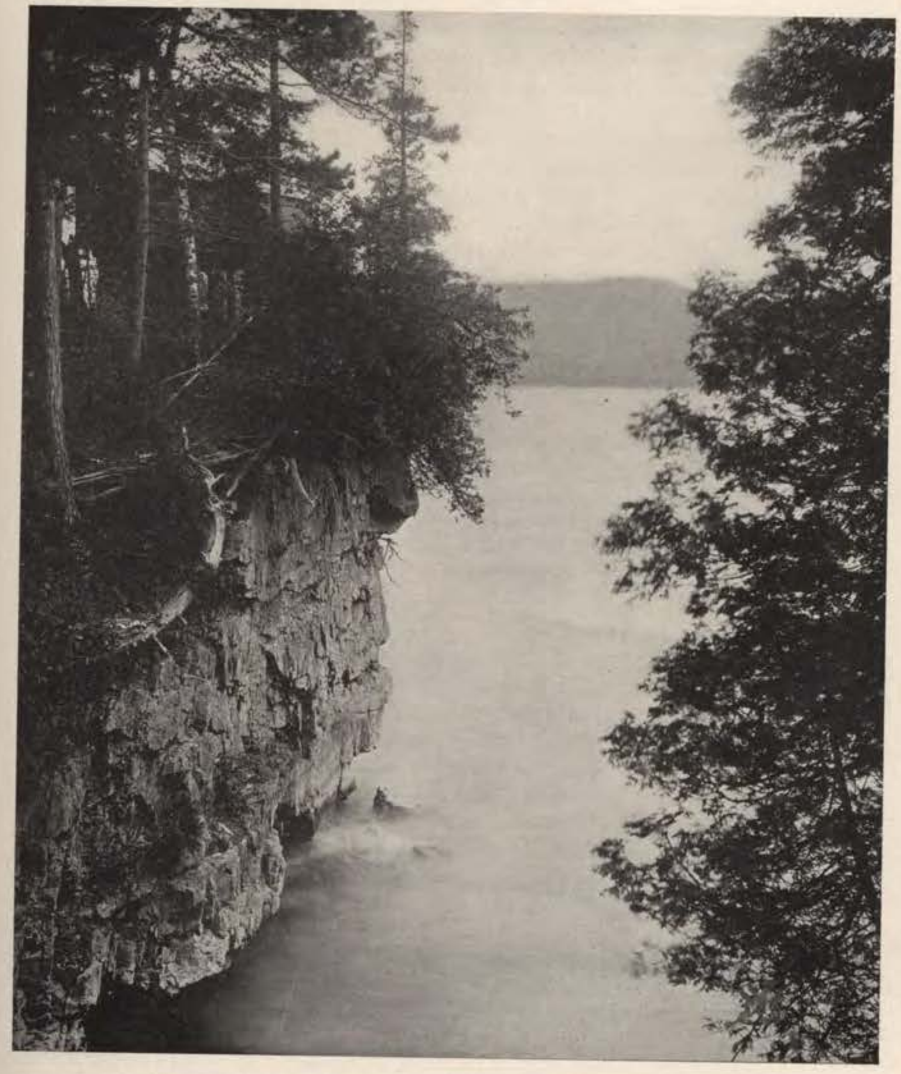
Besides the references given above it may be noted that Dr. R. Ruedeman in Bulletin 90, N. Y. State Museum has revised the nomenclature of the cephalopods of the Champlain Valley and has figured a number of the species from Fort Cassin and Isle La Motte, the latter being Chazy.

On the lake shore the Beekmantown does not occur between Providence Island and Thompsons Point which is formed largely of this limestone the cliffs of which are shown in Plates L and LI of the Sixth Report, one of which is here reproduced, Plate LI.

Everywhere the Beekmantown is a hard, dark, gray stone when found in its typical condition.

Brainerd and Seely in their study of this formation in the Champlain Valley have divided the formation in several sections A, B, C, D.

PLATE LI.



HEAVY BEEKMANTOWN CLIFF, THOMPSON'S POINT.

North in Canada and south through the Champlain Valley the Beekmantown is an extensive formation. Professor Seely thinks that there is at least two thousand feet of rock in the limestones of this age in Vermont.

Seely says that "Division A conforms in most features to the early known Calciferous."

This division consists largely of magnesian limestone, yellow when exposed to the weather though it is originally dark gray.

Section B is a hard stone which weathers white or very light. C is made up of "alternating beds of magnesian limestone and sandstone. Weathered portions very nearly resemble fine grained wood." Division D contains a variety of limestone pure or sandy. It is in this that fossils are most abundant. Section E is mainly a tough, magnesian limestone "with occasional pure limestone and rarely bands of slate." This division is also very fossiliferous.

CHAZY LIMESTONE.

As will be seen when the different towns are considered, the Chazy appears in numerous localities in the area included in these pages. Nowhere does it come to the surface as extensively as does the Beekmantown, but it is more uniformly fossiliferous, none of the outcrops being destitute of fossils and most affording them abundantly.

To Brainerd and Seely we owe much for their pioneer study of this formation. Others had long prior to the work of these investigators studied and written more or less of the Chazy of this region, but while the results obtained by these earlier geologists are not to be neglected, the papers published by Brainerd and Seely are so much more thorough and complete than any that preceded that they are the real foundations for all future study.

As in the case of the Beekmantown, the Chazy is divided by them into three divisions, A, B, C.

A, the lowest lying when in place immediately upon the Beekmantown is partly limestone and partly sandstone, the latter being usually lowest. This bed is often completely filled with small fossils.

B or Middle Chazy, is that found at Chazy Village and gives the name to the formation. It is especially characterized by the Maclurea magna, which large shell is very abundant in some layers. Large masses of Stromatocerium are also found in it.

C or Upper Chazy, is also very rich in fossils, both large and small. In some of the layers as one mentioned later on Isle La Motte, there are numerous and most interesting cephalopods and trilobites. As will be seen probably the best exposure of the Chazy in all its divisions is on Isle La Motte for nowhere else in the Champlain Valley are these so well displayed.

In Bulletin American Museum Natural History, N. Y., vol. VIII, pp. 305-315, will be found an excellent article on The Chazy of Lake Champlain by Messrs. Brainerd and Seely. Other articles useful to the student of the Chazy of this region are Fauna of the Chazy Limestone, Dr. Percy E. Raymond, Am. Jour. Science, vol. XX, pp. 353-382. Contributions to the Fauna of the Chazy Limestone on Valcour Island, G. H. Hudson Report State Paleontologist, N. Y. 1903, pp. 270-295, Plates 1-5. Brainerd and Seely Bulletin, G. S. A., vol. II, pp. 293-300, also Trilobites of the Chazy Formation in Vermont, Dr. P. E. Raymond, Seventh Report Vermont Geologist. The rock of the Chazy is mostly limestone.

According to T. G. White "The capping bed of the Chazy when well exposed seems to be a very constant and characteristic layer of very fine grained sandstone or quartzite." Also "The change to beds carrying a Trenton fauna is usually abrupt the latter formation consisting of much more thinly bedded and usually softer limestone and shales."

Although some of the Chazy beds resemble those of the Trenton as a rule they may be separated from them without difficulty even in the absence of fossils. The Chazy is generally coarser and lighter in color than the Trenton and is more heavily bedded.

Large fossils are not found at least in abundance, in most of the beds, but they do abound in a few of the Middle and Upper layers.

In the Maclurea beds of the Middle Chazy there are layers full of this large gasteropod and as will be seen, many interesting cephalopods have been found in the Upper Chazy of Isle La Motte.

More definite information as to the Chazy of certain localities will be given later.

As will be seen later, the Chazy extends from Isle La Motte south to Grand Isle where it appears on the west shore, thence to the north end of Providence Island. It does not then reappear before a small outcrop in Charlotte is reached and a little farther east of McNeils Point, and south along the road to Thompsons Point and at Balls Bay, where there is a larger outcrop than in most of the localities.

From here it goes on south to Shoreham and Orwell. From Basin Harbor to Button Bay the shore rocks are all Chazy, but south of Button Bay the formation does not appear on shore until we reach an outcrop not far north of Chimney Point. Here it shortly disappears to come to the surface again at Orwell where it comes to the lake about the middle of the town, though it is found farther north inland east of the Beekmantown. There is little Chazy south of Addison County.

In the accounts of different towns various other small areas of this rock will be mentioned.

BLACK RIVER LIMESTONE.

This formation crops out at several localities, but nowhere in any large areas, the largest being on Grand Isle. For the most part the Black River is a jet black very finely grained limestone, especially characterized by its even fracture, so regular that in many places blocks sufficiently rectangular to be used without further dressing for building may be broken out and many of the old stone houses built near the lake are of this stone.

The lowest beds, however, are not black, but a bluish shade still retaining the compact fine grain of the rest of the rock. In general this formation is nearly destitute of fossils, but some thin layers are very full and in most a few can by diligent searching be found and as the Columnaria, Stromatocerium, Maclurea, etc. are large and therefore conspicuous they usually serve well in identifying the formation. Some of the masses of Columnaria halli are very large.

The most remarkable display of corals that I have seen is in a cliff on the west side of Button Bay Island where there is a layer two feet wide composed almost wholly of Columnaria and Stromatocerium, which have so weathered that they stand out with wonderful distinctness. The Black River is found at Highgate though in no great amount, and on Isle LaMotte it is also seen and on Grand Isle.

There is an old quarry south of Larrabees Point from which many years ago this stone was quarried and sawed for black marble and here as elsewhere in the upper layer of the formation there are abundant specimens of Parastrophia hemiplicata.

TRENTON LIMESTONE.

In general there is little difficulty in distinguishing the Trenton and Black River, though some of the beds resemble in color and texture those of the latter. In variety of beds there is no resemblance for while the Black River has very little variety, the Trenton presents great changes in the different layers. The Trenton beds are dark, but usually lighter than the dense black layers of the Black River.

Most of the Trenton beds are fossiliferous and afford the characteristic species, but a few are barren. The most northern exposure of the Trenton is at Highgate. It is also seen abundantly on Isle La Motte and Grand Isle where it covers nearly half of the large island.

There are only insignificant outcrops of Trenton between these and Charlotte. There are small areas in Ferrisburg, the southern third of the Panton shore and the southern half of Addison shore. The same formation is found excellently displayed at Chimney Point and in Bridport and Shoreham and Orwell.

As Dr. Richardson shows in his article in this Report, it seems certain that the area covered by the Trenton extends much farther over the State than has been supposed and that not only of the mountains, but as well between them and the Connecticut River there are Trenton areas of considerable extent so that it seems probable that this formation is more extensive than any other over the whole State.

Most of the Trenton beds have not been greatly disturbed. Some show crushing and much folding and occasionally faulting.

UTICA SHALE.

In Vermont as in Canada, New York and elsewhere there is in many of the exposures no separation between the Trenton and the Utica for while the latter is almost wholly shale and the former limestone, yet in places there is compact limestone bearing Utica fossils and shale with Trenton fossils.

Moreover in some localities the Trenton passes into the Utica so far as the contained fossils indicate and the same compact black limestone is found in each and even on the same block of stone characteristic fossils of each period are found.

The Utica is not here rich in fossils, large beddings being apparently quite destitute, but there are some layers that yield in some abundance Triarthrus, Schizocrania, Diplograptus and other well known Utica fossils. Far more than any other of the Ordovician formations the Utica is tilted, folded and in every manner disturbed. It also frequently is filled with calcite veins of various widths and the clear white calcite is very conspicuous as it is seen in the black shale.

Compression and cracking are also seen in some of the Trenton, but in this formation it is by no means as pronounced or as common as in the Utica. Utica is found in greater or less amount in all the towns which border the lake and in some there are outcrops east of the lake. The whole of the Alburg peninsula, North Hero Island and much of Grand Isle are of this shale. So too Colchester, Appletree and Shelburne Points are of the Utica Shale.

Juniper Island and the Four Brothers and Rock Dunder are entirely Utica. In many of these localities the rock is very regularly jointed and the cleavage planes are as smooth as if cut with a knife.

In the 1861 Report on the Geology of Vermont the Utica is recognized, but a part of it is assigned to the Hudson River group and these two are treated as distinct. This is an error for there is in Vermont only the Utica. In a few localities not only thin, or at

CLIFF OF UTICA SHALE SOUTH OF SANDBAR BRIDGE.

any rate not more than a very few inches wide, veins of the white calcite occur, but there are wide masses cutting the shale like large dikes several feet wide. These are however rare.

It is evident that at one time the Utica covered the northern part of the lake east of Isle La Motte and reached south to Shelburne Point and probably considerably farther. Plate LII.

The Utica is especially conspicuous in lake shore cliffs at St. Albans Bay, Georgia, Milton, Colchester and Burlington along the line of what Logan called the Great Fault.

In all these places the Cambrian and Utica both come to the shore and the Cambrian is seen as a light or red rock of varying thickness from a few feet to twenty or more, lying upon the black shale of also varying thickness. Sometimes the sandrock is thickest, sometimes the shale.

Finer examples of a great overthrust fault cannot be found, and in places as at Rock Point just north of Burlington, the shale has been cut away by the waves from the sandrock so that the latter projects a few feet and the underside is well slickensided.

According to Sir William Logan there are two great faults between St. Albans Bay and Stanbridge which are connected with the Quebec Group, of the earlier Canadian geologists.

The western fault runs from St. Albans Bay through Swanton, Highgate Springs, and Phillipsburg to Stanbridge and the eastern from the mouth of the ravine at St. Albans Bay by Smiths limeworks, the Missisquoi Valley, southeast of Swanton the Rock River on the Canada line into St. Armands. South of St. Albans Bay they run into each other and continue for many miles south as one.

THE TERTIARY.

Although mainly outside of the special area we are discussing it would not be at all well to omit this formation. It is nowhere except in Waltham clearly defined within our area, but the older Vermont geologists may have been correct in regarding the iron ore at one time mined in Colchester as well as certain clays found in Milton, Swanton and a number of towns south as remnants of a bed of late Tertiary which extended through the State from north to south. It is certain that the lignite found at Forestdale and also in Waltham is of this age and anyone interested in the subject will find it fully discussed in the Fourth and Fifth Reports of this series.

THE PLEISTOCENE.

It is a tremendous step from Utica to Pleistocene, but with the small exception noted as Tertiary there are no rocks between in the region we are considering.

Everywhere the sands, boulder drift and clays of the Pleistocene are found resting directly upon the Ordovician or Cambrian rocks. This is well shown in Plate LIII where at Clay Point the Champlain Clay is seen lying on the upturned Utica. Moreover the underlying Ordovician rocks are deeply grooved, striated and smoothed by glaciation.

Because of the extensive investigations of Professor Fairchild and Goldthwait related in preceding articles in this Report it will not be necessary to devote much time here to this period. It is sufficient to say that everywhere over Western Vermont the student of Pleistocene geology will find abundant and most excellent material for his examination.

So far as all evidence goes Western Vermont was dry land during the immense interval that existed between the end of the Ordovician and the Pleistocene.

IGNEOUS DISTURBANCES.

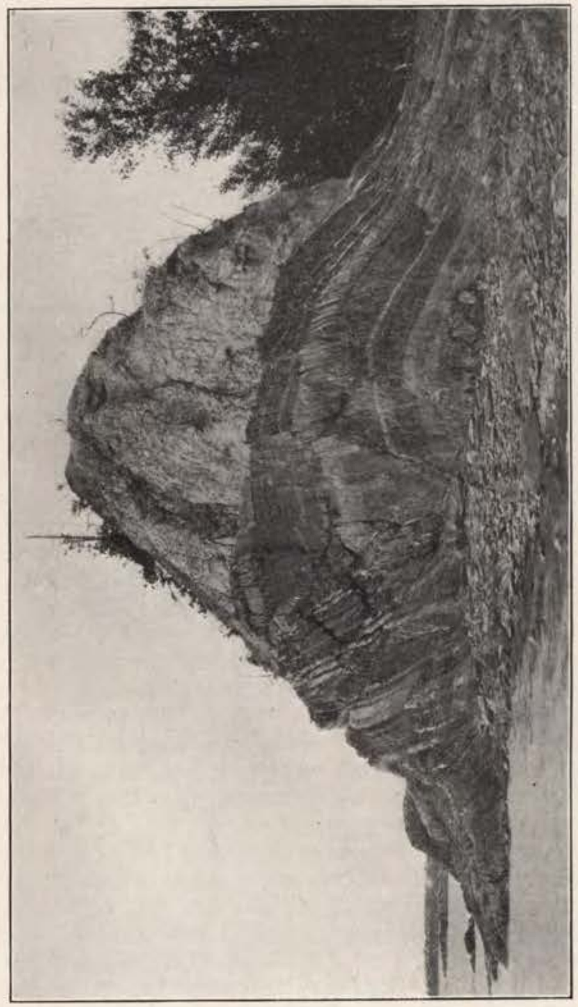
The great disturbance which resulted in the St. Lawrence and Champlain Fault of the Canadian geologists has been noticel. Lesser faults are not uncommon throughout this region and as is well known, in the immediate region of the Green Mountains disturbance of every sort is everywhere present. Probably during or soon after the close of the Green Mountain uplift and the attendant metamorphism and folding of the rocks numerous dikes were sent up through the Ordovician strata of Western Vermont.

In former reports these have been mentioned and more or less fully described. The reader is especially referred to the Third and Fourth Reports where the greater portion of the dikes are considered. Grand Isle and Shelburne Point are traversed by dikes more than any other part of the State.

Grand Isle is about thirteen miles long and its strata are cut across by over forty dikes which are from a few inches to several feet wide. According to Dr. Shimer these dikes are technically Monchiquites or Augite-camptonites much the greater number being the former. Shelburne Point is cut by at least twenty-five dikes of as usual greatly different widths.

Kemp and Marsters have studied these and published their results in Bulletin U. S. G. S. 107. The *Trap Dikes of the Lake Champlain Region.* Technically these dikes are according to Kemp and Marsters, Bostonite, Camptonite and Monchiquite, the first predominating. There is a dike which cuts across the point which is of peculiar appearance and differs from other dikes of this region. It is about twenty feet wide and is, instead of ordinary dike rock, a very conspicuous breccia. To quote the description in the Bulletin, "It is a most remarkable rock and con-

PLATE LIII.



CLAY POINT, COLCHESTER.

sists of angular pieces of slate and red quartzite cemented together by an igneous base.

The cementing base is not very fresh in the attainable specimens, but is clearly of the same nature as the ground mass of the bostonites. The included fragments are angular and do not appear to be notably altered by the fact of their inclusion. They preserve sharp edges and polarize like ordinary sedimentary rocks.

Two explanations may be offered of this rock, one that it has been extruded on a line of previous faulting which has broken up the walls and left loose material to be gathered up by the intrusive magma." This explanation has the greater weight with the writers.

The other is that it represents only the upper portion of a dike and thus contains the float material which the advance of an intrusive body that forced its own passage would naturally gather from the walls.

In an article in Journal of Geology, vol. XXIII, pp. 167-168. Mr. Sidney Powers offers a different explanation of the inclusions in dikes. Of the dikes we are considering he says, "The origin of the inclusions appears to the writer to have been the shattering of the walls of the dike by the intrusive magma as it ascended through the pre-Cambrian, Cambrian and Ordovician.

Little corrosion could take place in fragments caught in such a magma and shot upward to their present position where they would be quickly chilled because of the inadequate supply of heat and lack of time. The invaded rocks would be comparatively cold when ripped off and would therefore have a chilling effect upon the surrounding dike-magma in a twenty foot dike."

A short distance south of the above dike, at Nash Point there is a second containing inclusions with the difference that the included fragments are more or less rounded as if water worn and there is also a greater variety of material than in the former dike.

There is not only red sandrock, shale, but gneiss, hornblende, schist, limestone, and perhaps other rocks. The dike is twelve feet wide. Some of the inclusions are large, even in rare cases several feet in diameter and the exposed surface of the dike as seen from the lake is very striking.

The character of this dike and especially the fact that many of the included rocks are rounded on the edges have greatly puzzled observers from the time of the earlier Vermont geologists down.

Professor Kemp says as to this "The inclusions indicate that the dike has come from a great depth and that it has passed through norite, gneiss, Cambrian strata and slate." He thinks that the apparent water-worn appearance of some of the inclusions is due to the "corrosion of the dike." Mr. Powers says

(l. c. page 168). "The rounded character of some of the inclusions is probably due to mechanical causes, principally the friction of the blocks against the walls of the dike and against each other in ascent. The thickness of the sedimentary series in the region is about 12,000 feet from the top of the pre-Cambrian to the horizon of the dike. Hence the pre-Cambrian norite inclusions must have risen over two miles and their edges would be necessarily rounded."

There is also on this same point a sill of bostonite full of inclusions all of which are the Utica shale from the adjacent walls. One of the most singular inclusions I have seen in any dike is on Grand Isle in Beach Bay on the west shore. Here the dike is only thirty inches wide, but it has brought up as it came to the surface a strip of the Chazy limestone full of rhynchonella. The band of limestone is nowhere more than two inches wide and often less and though in the midst of the igneous rock the limestone is almost wholly unchanged.

The largest dike in western Vermont is forty feet wide. This is located not far south of those mentioned as containing inclusions.

GENERAL GEOLOGY OF DIFFERENT TOWNS OF WESTERN VERMONT.

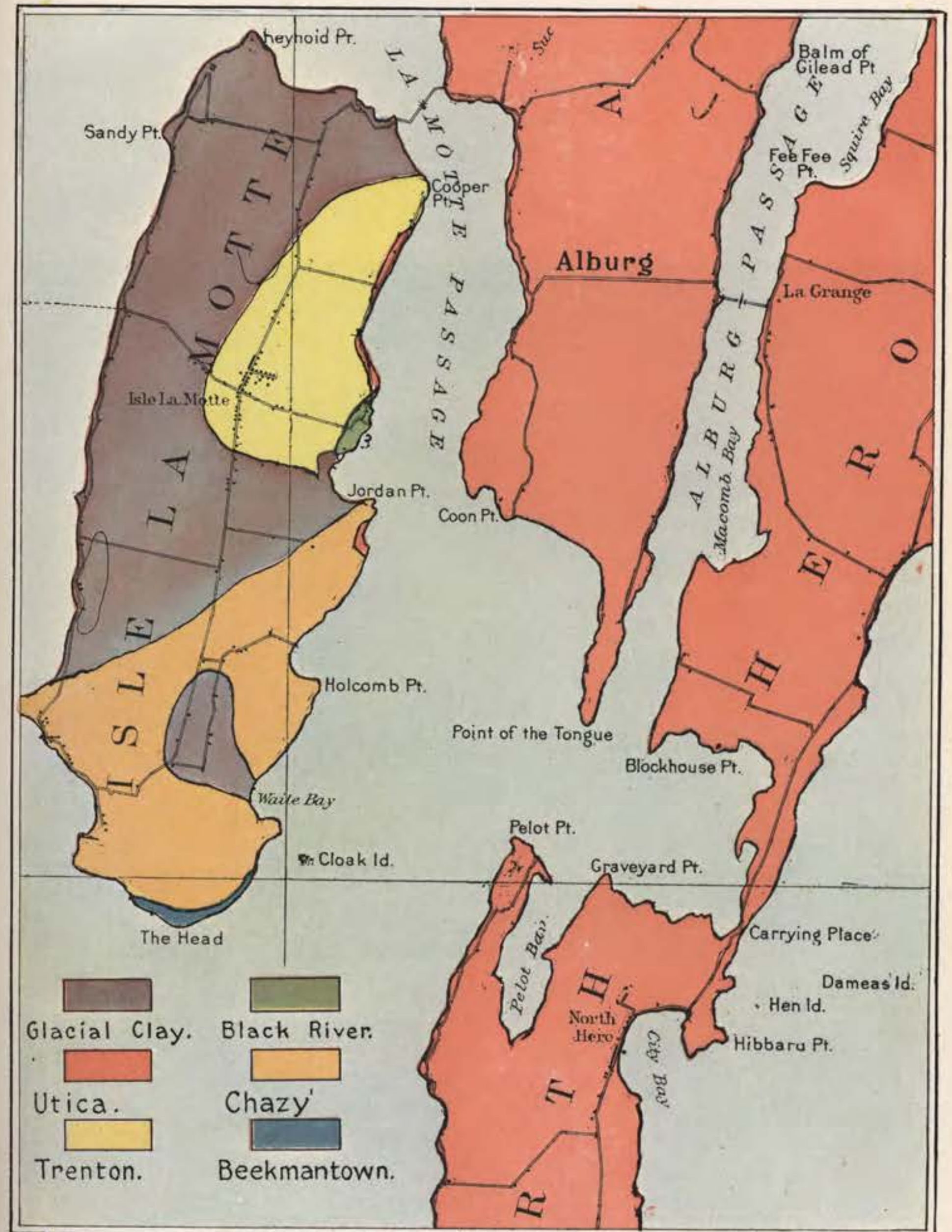
Though necessarily involving a certain amount of repetition the following pages aim to give some idea of what formations are to be seen in each of the towns studied and as well of the extent of the formations in the towns, in order that a casual visitor may be guided in his investigations should he wish to study the geology of any of the localities named. It should be remembered that in this article only the areas between the mountains and lake and especially those towns situated along the lake will be considered.

GRAND ISLE COUNTY.

This small county composed of the Alburg Peninsula and the islands south of it, Isle La Motte, North Hero and Grand Isle is a most charming and in some parts interesting region for geological work. Valcour Island, as it belongs to New York will not be discussed here though it really belongs to the group.

ALBURG. This town may be dismissed with brief mention as it consists entirely of Utica Shale which like all of this rock in Vermont is not rich in fossils and affords but very few species even where fossils are to be found. The common fossils are Diplograptus foliaceus, Triarthrus beckii, etc. At a locality on the east shore of Alburg a number of entire specimens of Triar-

PLATE LIV.



GEOLOGICAL MAP OF ISLE LA MOTTE.

PLATE LV.

BEEKMANTOWN, STRATA, AT THE HEAD, ISLE LA MOTTE.

thrus have been found, but as every collector well knows, only the glabella is usually found.

Isle La Motte. This island has long been known as an interesting locality for the geological student as on it are found many outcrops of various horizons. Unfortunately for the geologist more than half of the island is covered by clays and sands so that the underlying rock is wholly concealed.

Over the remainder however there are many very interesting exposures of Ordovician strata, as shown by Plate LIV.

Over the northeastern portion of this island there are Trenton beds and a little Utica, while south of this is a small area of Black River and all the southern part is Chazy, except a very little Beekmantown at the extreme southern point.

Taking up these in the order of age we find first the *Beekmantown* at the south end of what is known as the Head.

The contact between the Beekmantown and the overlying beds of Chazy is very distinctly marked. Brainerd and Seely made out sixty feet of this rock at the Head. It is mostly thin bedded, but there are a few thick, heavy layers. Most of these are very silicious and barren as to fossils. Sun cracks, worm burrows and other shallow water evidences are common in the thinner layers. In color most of this rock when not bleached by weathering is dark gray. The upper bed weathers a light buff, though dark bluish when freshly broken. This layer is characterized by the presence of the little fossil Isochilina. This layer is of considerable thickness and is very hard and solid. It is well shown in Plate LV.

Chazy Limestone.—The Chazy covers most if not all of the island south of the large swamp which divides it into a northern and a southern portion. All the divisions of the Chazy are found and along the east shore and around the Head these rocks may be followed for at least six miles. Most of the beds are Lower and Middle Chazy, but there are some of the beds of Upper Chazy. Brainerd and Seely who more than any others have carefully studied these rocks make the thickness of the Isle La Motte Chazy as 640 feet. Plate LVI shows Chazy at Isle La Motte.

The Chazy rocks begin at Jordan Point just south of the swamp on the east shore and, with some little interruption by small bays, south to Fisk Point. It occurs abundantly inland especially in Fleurys and Goodsells pastures where the thin soil has been washed off in many places leaving the rock bare. In Goodsells pasture the rock is Middle Chazy, in Phelps pasture Upper and going south from here on the main road the Middle Chazy appears and in some layers great numbers of Maclurea magna may be seen. Like many other beds on this part of the island the rock is in places very rich in fossils and it has never been thoroughly studied so that without doubt careful exploration would reveal many new forms. In Hills pasture there are beds of Upper Chazy which have yielded many large cephalopods and trilobites. Some of the large blocks taken out here have been full of conspicuous fossils and when sawed and polished have made splendid specimens of this portion of the formation. Many years ago Senator Edmunds had several slabs of this stone gotten out and prepared for use as panels in a house in Washington hence the layer has been called the Edmunds layer.

At the southern end of the island there are two quarries, Fisks and Fleurys, which have been worked a long time, the former over a century. These are mostly in the Middle Chazy.

Black River Limestone.—There is only a single small area of this formation on Isle La Motte. This is on the east shore just north of the swamp. It is perhaps a hundred and fifty rods long and but a few rods wide. Hills quarry not now used, is in this limestone and several houses on this island are built of stone from here. The rock presents the usual characters of the Black River, few fossils in most of the beds though in a few there are more. At the north where this rock joins the Trenton there is a small fault, but nowhere is there evidence of much disturbance.

Trenton Limestone.—At the north the Trenton is seen first at Cooper Point, but it undoubtedly extends farther north, but is covered by drift. From Cooper Point south this formation reaches about two miles passing through the village increasing in width. With the exception of a small portion of the highest Chazy at the Head, the Trenton forms the highest ground on the island reaching 120 feet above the lake. This rock is found only in the northeastern part of the island and comes to the shore south of Cooper Point for about five hundred feet as the map shows, and none is found south of the swamp.

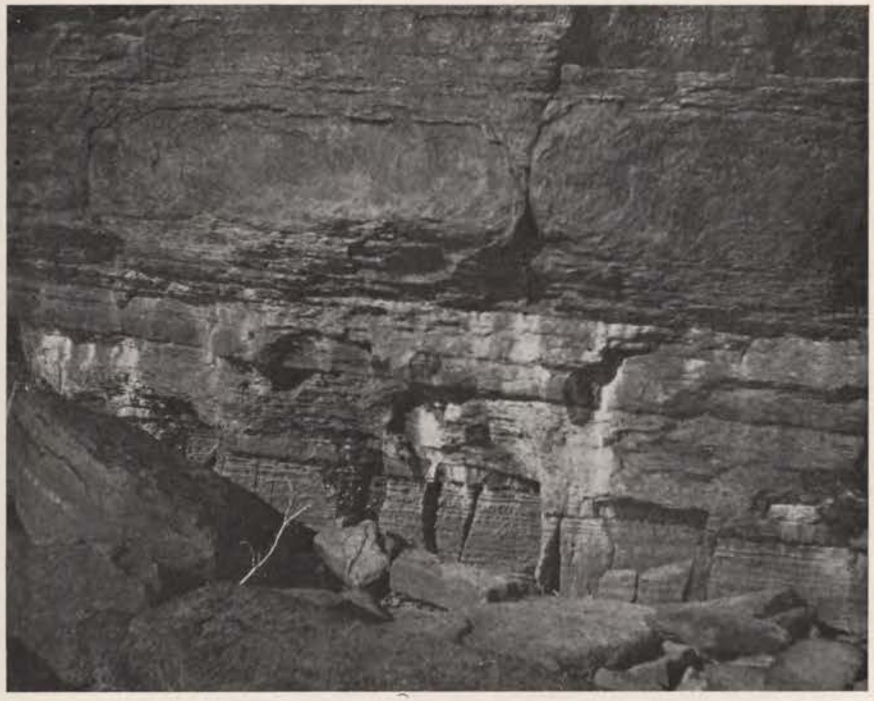
Cooper Point itself is a low headland about forty feet above the lake. Most of the Trenton here is black though there is a little gray. Some of the layers near the point are well filled with fossils and if carefully studied would give good results. Most, if not all of this rock is Upper Trenton. Some of the limestone not far south of Cooper Point is full of calcite veins and gives evidence of compression and disturbance.

A few rods north of Hills quarry the Trenton comes in contact with the Black River.

Utica Shale.—Evidently the Utica extends from Alburg under the lake and just touches the eastern shore of Isle La Motte, where it appears in only a few narrow strips running north and south.

Here as everywhere in western Vermont, this shale is greatly disturbed and often abundantly filled with calcite veins of various

PLATE LVI.



HEAVILY BEDDED CHAZY, ISLE LA MOTTE

widths. The shale fringes the shore for perhaps a mile and a half, but nowhere reaches far inland, never more than a few rods and often only a few feet. At its most southerly exposure the Utica is shoved against the brecciated limestone mentioned under the Chazy as this in turn is shoved up against more regular Chazy beds.

Pleistocene.—The prevalence of Champlain Clays over the north and west part of the island has been mentioned. As the map shows these cover more than half of the island. Wherever the underlying limestones are freshly uncovered they show very fine striations and are beautifully smoothed and often highly polished. Indeed Isle La Motte has long been famous for its glaciation. I have never found more than three or four sets, but Professor Adams reports eight sets in Hills quarry. This of course indicates much local glaciation.

North Hero.—Like the Alburg peninsula, this island is wholly underlaid by Utica Shale which has the usual characteristics of this rock. Around the shore at Hibbard Point there appear to be more fossils than elsewhere, especially Triarthrus and Diplograptus. North Hero seems to be a continuation of the mainland north, the lake having washed out the connecting rock.

Grand Isle.—As the map (Plate LVII) shows, much more than half of the area of this, the largest island in Lake Champlain is of this age.

Beginning with Wilcox Point and going north and northeast for six or seven miles and around Ladd Point turning south and following the shore to Allen Point and around this north for a couple of miles the entire shore save a few short sandy beaches, is of this shale. As will be seen, the remainder of the shore is Chazy and Trenton with some Black River, and a very short stretch of Beekmantown. This Beekmantown is seen only at the extreme southern part of the island less than a mile east of Phelps Point. It is exposed only in small outcrops, a few rods on the southern shore and a few just north. The rock is very hard, dark, highly silicious and sparsely fossiliferous, small Bathyurus, Isochilina, etc., a few species.

Providence Island is all but the northern tip and Stave Island wholly, of this rock.

The *Chazy* of Grand Isle is of much greater interest, as well as much more extensive.

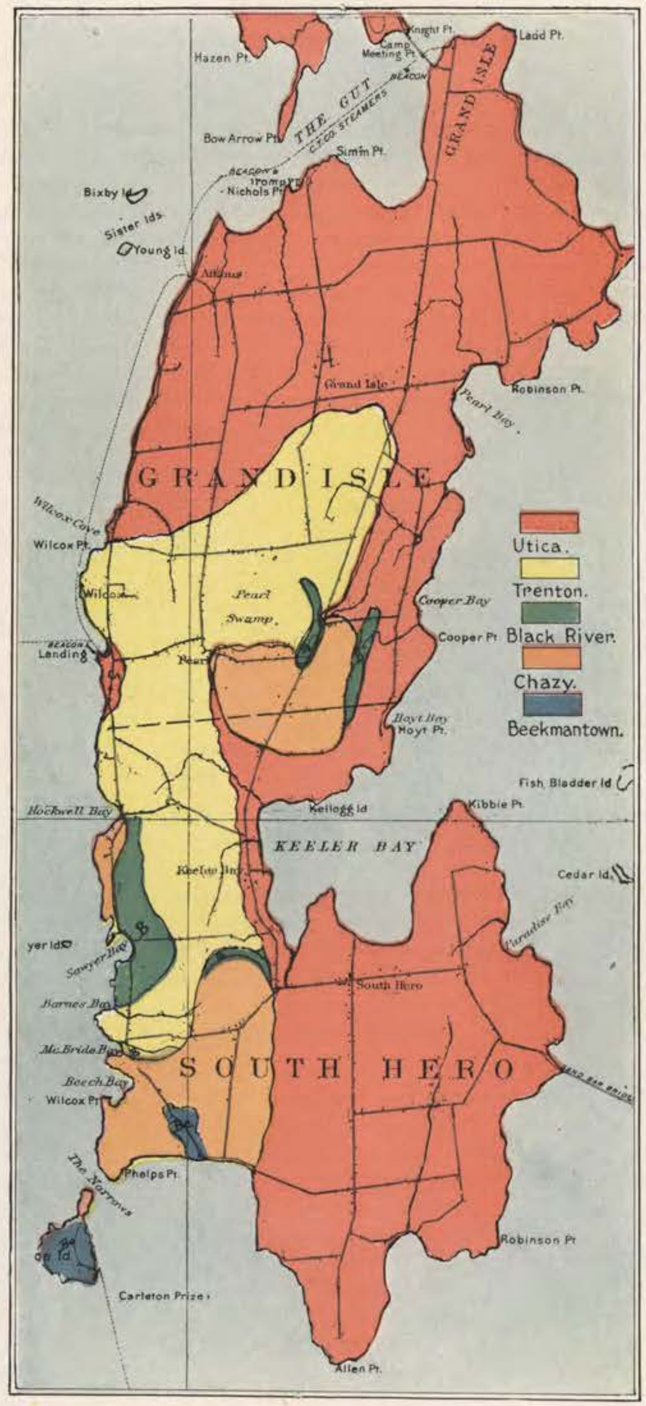
Beginning at Phelps Point at the southern part of the west shore the Chazy is continuous along the lake shore as far as McBride Bay where at the north side it is replaced by the Black River and Trenton and again Black River as far as Sawyer Bay where, on the north side, the Chazy comes to the shore and continues to the north side of Rockwell Bay. For the most part the strata are not greatly disturbed and usually they are thin, but some are heavy and at Phelps Point there are very heavy beds. A mile northeast from this point is a large mass of Lower Chazy forming one of the highest elevations on the island and just before reaching this hill there is east of the road a layer about four feet thick which contains Lingula limitaris of Seely and thus marks the bottom bed of the Chazy.

The diverse beds of the Chazy of Grand Isle indicate the great variety of conditions which prevailed during this time and this variety is well seen in going from Table Bay north to Rockwell Bay, a distance of over a mile. Sixty-six quite different beds are seen in this distance, most not more than a few feet thick and some only a few inches, each with characteristic structure and fossils. Some of the beds are strong and hard, others friable and crumbling, others shaly. A number indicate a muddy and often sandy bottom and rather shallow water; some clear, deep, still water. The whole thickness is not great, not more than a hundred and thirty feet. All indicate constantly changing marine conditions. In many layers low forms of life predominate, especially sponges. Indeed some layers are almost wholly composed of the small sponge Strephochetus occellatus of Seely and other species of this genus are abundant. Species of Solenopora are also abundant in some layers. Other beds are largely composed of Rhynchonella plena with perhaps a sprinkling of other brachiopods.

The Chazy here is usually gray, darker or lighter in shade and it is mostly Upper, or the division called C by Brainerd and Seely. The more sandy layers however are yellowish in color. The Chazy rocks are found well exposed along the lake shore and are most conveniently studied there, but there are two large areas somewhat inland, one not far north of Keeler Bay through which the main north and south island road passes, lying between the railroad track and the narrow strip of shale along the east shore of the island, and one in the southwest part at Phelps Point and from there reaching two or three miles toward Keeler Bay at the northeast. As has been intimated, there are some remarkably heavy beds in this second area, especially in a quarry from which a great amount of limestone was taken by the Rutland Railroad when building the long fill from Colchester Point to the island. This latter is largely Middle Chazy.

All of the Chazy on Grand Isle is unlike that on Isle La Motte, or at least so far as I have studied it and for this reason the two islands afford a most admirable field for study of this formation and such investigation would most certainly produce excellent results.

PLATE LVII.



GEOLOGICAL MAP OF GRAND ISLE.

Black River Limestone.—The outcrops of the Black River appear at six localities on this island. Some of these have the usual features of this stone, namely very black, compact, regularly jointed, fine grained, but there are some rather large beds which are bluish and contain numerous veins of white calcite. The Black River is the shore rock from the north side of Barnes Bay to the south side of Sawyer Bay, but away from the lake it goes north beyond Rockwell Bay and farther north there are two narrow belts, one on the west of the main island road and one adjoining the east side of the Chazy area east of the first named Black River. There is also a small outcrop of this stone in the southern part of the island northeast of Phelps Point, but it is too small to be indicated on the map.

Trenton Limestone.—Next to the Utica the Trenton is most fully displayed on Grand Isle. It does not show on the lake shore very largely, but is the backbone of the island. Between McBride Bay and Barnes Bay this formation is well shown and again from the north of Rockwell Bay for about a mile when the Utica for a short distance across Gordon Landing when again the Trenton north to beyond Wilcox Point. These exposures are the western edge of a large area which as an anticlinal ridge runs through over six miles of the island and includes most of the higher land. Everywhere the ordinary fossils of this part of the Trenton are fairly abundant, such as Trinucleus, Asaphus, Calymene, various brachiopods, Prasopora, etc.

North of Gordons on the west shore the typical limestone gradually passes through a similar stone, but with Utica instead of Trenton fossils, into shale. As has before been indicated, more than half of the surface of this island is covered by Utica Shale and by far more than half of the shore line is of this rock, probably three-fourths. There is nothing peculiar in the Utica here and there is no need to repeat.

FRANKLIN COUNTY.

The eastern towns of this county have not been studied and little can be said with certainty as to their detailed geology, but in general they are destitute of stratified rock and covered with the schists and gneisses of the Green Mountain region. It is possible that more careful investigation of some of these towns may reveal less highly metamorphosed rocks, but for the present we must pass them by with only general statements. The lake towns have been more thoroughly studied and contain beds of unchanged sedimentary rock with fossils. From the Lower Cambrian to the Utica all members of the Cambrian and Ordovician are to be found in greater or less amount.

HIGHGATE.—The rocks of this town have been studied for many years by both Canadian and American geologists and interesting exposures found. There is considerable Utica on the lake shore and less Trenton. East of this at Highgate Springs there is an eroded anticline in which are displayed a double series of beds ranging from Chazy to Utica. Dr. T. G. White has called attention to the appearance here of the "same zone found at Larrabee Point in the Trenton." The lowest of these beds is a bluish gray or dove colored stone, almost destitute of fossils. Other beds follow in succession. Sir William Logans account of the arrangement of strata at this locality was published in Geology of Canada, 1863, pp. 272-275.

SWANTON.—The rocks of this town are about divided between the Utica, which is found over the western part and the Lower Cambrian which is seen over the eastern half. Along the eastern edge of the Utica there is a long narrow belt of Chazy which has a nearly north and south axis. Extending through the Cambrian from the northern border of the town is a narrow belt of a conglomerate also Cambrian, an intraformational rock.

East of this mass there are three small outcrops of the same rock. The shale exhibits all of the characteristics of this rock, but none other. The Cambrian of the eastern part of the town is all of the Olenellus zone of Walcott. It is largely red sandrock, but there is also dark shale and a dark gray silicious limestone. There are near the Missisquoi River beds of the more calcareous phase of the sandrock which is worked as Champlain marble. In the arenaceous shale are found Ptychoparia, Olenellus, a few brachiopods and fucoid-like fossils. Mr. G. E. Edson, found on land owned by J. P. Kelsey in the decomposed shale the following:—Ptychoparia adamsii, Microdiscus parkeri, Olenoides marcoui, Dactyloides asteroides, Rustella edsoni, Agnostus interstrictus. South of this place in the silicious limestone I have found in abundance Iphidea labradorica and Kutogina cingulata, besides other species less frequently. The intraformational conglomerate contains fragments of all sizes of limestone and shale in which as in the cementing material Cambrian fossils can be found, and the same in both fragments and binding material.

The Chazy is represented in Swanton by a dove colored, compact limestone quite different from that in most Chazy rocks. It is a very pure carbonate and is used for lime making at Rich's Lime works and also near St. Albans at the Fonda works. Very few fossils have ever been found in this rock though it has been broken up for the kilns for many years. An occasional Maclurea serves to give its age. A small amount of this stone is sawed by the Barney Marble Company and polished when it makes a very neat dove colored stone of attractive appearance.

ST. ALBANS.—Very much as in Swanton the rocks of St. Albans are half shale and half Cambrian. The same varieties of Cambrian rock, sandrock, shale, and limestone occur here. Swanton has thus far proved a better collecting ground than St. Albans, though some interesting things have been found by Mr. Edson in the latter town.

In most exposures along the line of the Great Fault the Cambrian rests directly on the Utica and at St. Albans Bay this is the case, and also away from the lake. Mr. Edson, speaking of the Chazy, says: "Near the north line of the Brooks farm on the east side of the road the limestone is seen on the side of the hill at which point the Cambrian lies above it forming a steep cliff. * * * At this point the Chazy formation is not only seen passing under the Cambrian, but here is a large mass of Cambrian rock forming a ridge for a short distance some fifteen feet in height, which not only rests upon the limestone, but is so placed that the Chazy formation appears on both the eastern and western sides of the ridge."

There is a large exposure of Chazy a little west of the middle of the town between the Utica and the Cambrian and a much smaller one through which Stevens Brook runs some distance north of St. Albans Bay. The large mass of dove limestone in the north part of the town in which the Fonda Lime kilns are located has already been mentioned.

The Trenton is found in St. Albans, but only in small amount. The Catholic Church at the Bay stands on Trenton rock, indeed all four of the formations mentioned are found. Other outcrops of Trenton are on the east of the highway near the Foss farm and farther on west of the road on land belonging to Stephen Abler. Mr. Edson collected from the Trenton near the Catholic Church at least twenty-five species of fossils.

GEORGIA.—None of the beds of western Vermont have been as well and widely known as those of Georgia. From the time of Adams to the present some of these beds of Cambrian have been studied and many species collected. Indeed for some years the Cambrian of Georgia was known to geologists as the "Georgia group." Later Dr. Walcott who more than any other has studied these rocks called them the Olenellus zone and finally after the discovery of larger deposits of the same age in the west he gave the name Waucobian to this group of Lower Cambrian rocks.

In the Tenth Annual Report of the United States Geological Survey and later in numerous other publications Dr. Walcott has discussed the species from the Parker ledge and the rocks near it.

While Georgia has always been best known because of its Cambrian this is not the only rock found here. Mill River flows for a considerable distance through a channel cut in the heavily bedded Chazy limestone. Also on what is known as the Haynes farm there are good outcrops in a hillside pasture and north the Trenton may be found. The Utica too is found along the lake shore, but does not occur in any large amount in this town.

CHITTENDEN COUNTY.

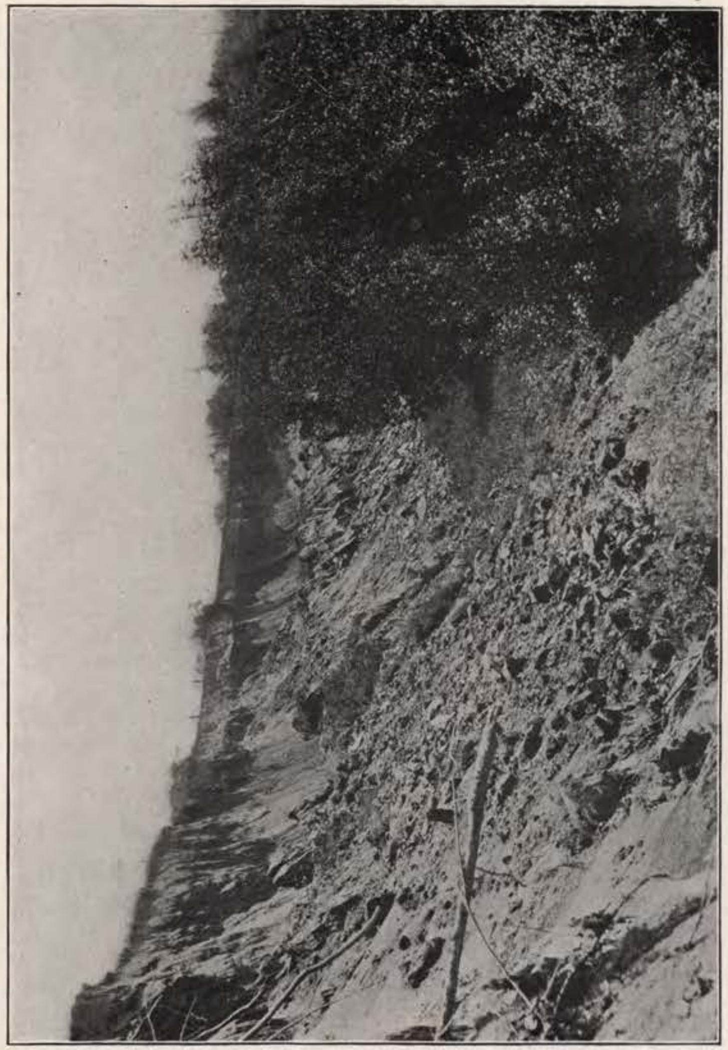
MILTON.—In this town and also that next south, the rocks are much disturbed and need a great deal of careful study before satisfactory conclusions can be reached. Apparently a large portion of the rocks of the town are Cambrian and the higher elevations as Arrowhead Mountain, Cobble Hill, Fox Hill are of this age. The same narrow band of Utica seen in St. Albans and Georgia along the lake shore is found here.

Cobble Hill is mostly silicious limestone at the base but there is also red sandrock and shale. Eagle Mountain is mostly red sandrock though at the north side there is conglomerate and low down Utica. Fox Hill is mostly silicious limestone and Arrowhead is mostly schist. The old Lamoille delta plain described by Hitchcock in the Fifth and Sixth Reports covers a large area in Milton south of the village. In general the rock of Milton may be said to be red sandrock on the west, Georgia slates through the center and quartzite on the east in the northern part of the town, while south extending through the town is a large belt of Beekmantown. Probably at Checkerberry there is a little Chazy. Near the lake shore there is a small bed of Nematite which was mined for a short time fifty years ago. The ore appears to be good, but the quantity was too small. Mr. D. B. Griffin as field assistant has for several years been working over the rocks of this town and those of Colchester and to his explorations I am mainly indebted for the facts given.

COLCHESTER.—The Milton rocks are largely continued south into this town but the beds in Colchester appear to be even more varied and folded than in Milton. In the immediate vicinity of the lake at Colchester Point the rock is Utica in considerable amount. North of this the red sandrock comes to the lake and extends inland to cover more than half of the town. Not all of this is however typical red sandrock for the slates of Georgia come down into this town to some extent. There are also heavy beds of quartzite. In the eastern part of the town there are large beds of gray silicious limestone some of which certainly and all of which probably is Beekmantown in age.

Not only Lower Cambrian, but near Stony Brook Ridge there are small outcrops of Middle Cambrian and near Coon Hill what may be Upper Cambrian, but in any case these are only in very small areas so far as is now known. As elsewhere, most of the Cambrian is very poor in fossils, but in some of the

PLATE LVIII.



BANK OF WINOOSKI RIVER AFTER SLIPPING.

red sandrock Ptychoparia are abundant and in some quartzite beds north of Malletts Bay there are thin layers very full of glabellas of Olenellus thompsoni, but bearing scarcely any other fossils. Some of the layers about this bay are full of worm borings and various problematical fossils, tracks, etc.

The great variety of the Cambrian rocks of this region is shown by the fact that on the shore of Malletts Bay Mr. Griffin following the exposures was able to distinguish over two hundred beds varying in thickness from a few inches to thirty-five feet.

The great beds of gray limestone which extend for miles through western Vermont, always at some distance from the lake, have been mentioned on previous pages. The stone varies considerably in different localities. Much of it is highly silicious, much more purely lime carbonate. At the Lime Kilns in Colchester the rock has been burned for many years, as it still is, and excellent lime has been made. Diligent search for fossils has been carried on for more than fifty years with little result, proving the barrenness of the rock.

In the bed of a brook where the limestone was waterworn and weathered Mr. Griffin has collected good specimens of the large Rhaphistoma canadense, Cryptozoon wingi and some undetermined fossils, but the two clearly identified show the Beekmantown character of the beds at that point. And from the apparent continuity of the whole mass it seems safe to call it all of this age, at any rate until more fossils are discovered. The limestone extends south from Colchester and Milton through Essex and Hinesburg into Monkton a distance of more than twelve miles. The width is usually three or four miles.

In one or two localities in this town there are beds of distinctly marked oolitic rock the age of which has not yet been determined. As has been noticed there is no intention of discussing other than very briefly, the surface geology of the region but one occurrence is of such interest that it may be mentioned with some detail.

Early in June, 1914, Mr. G. R. Stackpole principal of the Winooski High School called my attention to a peculiar occurrence in the river north of the village and in his company I visited the place and found what seems worthy of record.

At the time Mr. Stackpole wrote a brief account of this in the Burlington Free Press. On the night of June 1st a landslide changed the face of a bluff to a very large extent as follows: Before the slide the bank consisting of about fifty feet of nearly pure yellow sand and underlaid by ten or fifteen feet of the same sand but containing small boulders and pebbles, the whole resting on a bed of stiff blue clay of unknown depth. This clay bed extended west under and across the river, which at this point was then three hundred to four hundred feet wide, and continued on the west bank.

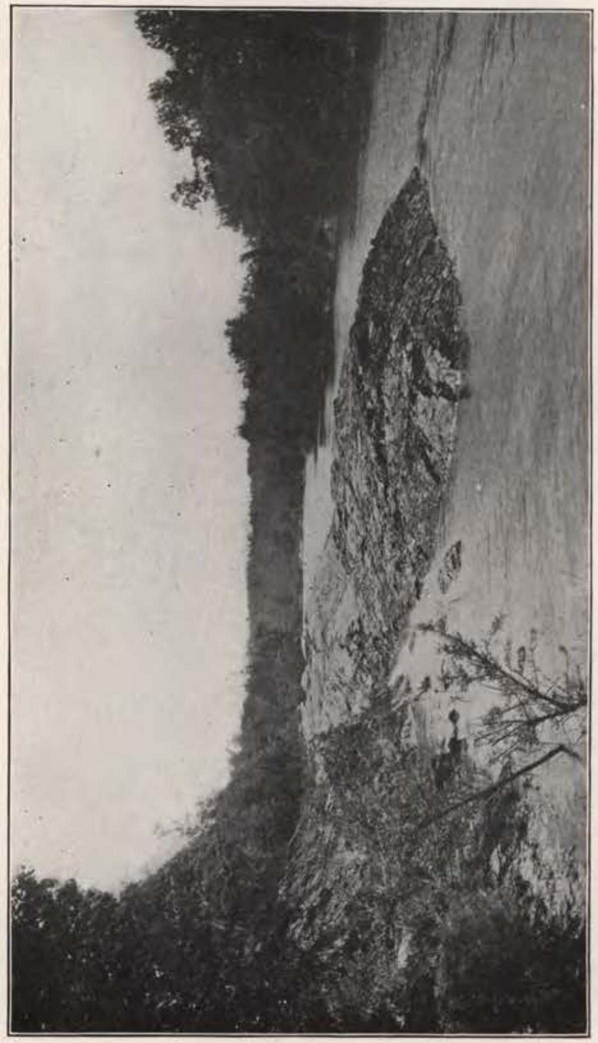
The river was about ten feet deep next the east bank. Mr. Stackpole describes the east bank before the slide as being in a double terrace. Above there are several acres of level pasture from the western edge of which the bank descended vertically for fifty feet, then there was a level platform some sixty feet wide and the western edge of this fell thirty feet to the river, the last four or five feet of this bank being clay. During the night without noise, so far as anyone in the neighborhood can say, the upper part of the bank slipped down so that in the morning it was as seen in Plate LVIII which is from a photograph taken a day or two afterwards by Mr. W. E. Prior as were the other views shown.

At this time the bank was forty feet in vertical height, then below this was the level, on which the more or less disturbed white birches are standing or leaning, which is from seventy-five to a hundred feet wide and from this a second nearly vertical bank some ten feet descended to the water when the river is high, but at low water in summer there is a flat shore several feet wide between the bank and the water. Where the river had flowed with ten or more feet of water there was a mound of clay as seen in Plate LIX. This mound of clay was about a thousand feet long from north to south. Plate LX shows the north end, the river here flows nearly north and south, taken from a point quite near it. The clay mound in the river evidently rose gradually, though all in a single night, as the top is covered by the undisturbed bottom of the river, the sand and pebbles being in no wise displaced from their former position. Of course the channel of the river has been narrowed nearly one-half for the length of the clay mound, and this is somewhat less than a thousand feet.

The main mass however, is not far from four hundred feet long and from this there extends southward a long narrow strip but a few feet wide, finally coming to a point at a little ravine through which a brook enters the river. At the widest, the northern part, the width is about seventy feet, but most of it is much narrower than this. A ravine at the north and another at the south seem to have determined the limits of the slide as it begins and ends abruptly at these. Both are deep enough to cut through the sand down to the clay. This movement of the bank has added interest as it appears to be almost precisely in principle the same in a small scale as the slides in the Panama Canal.

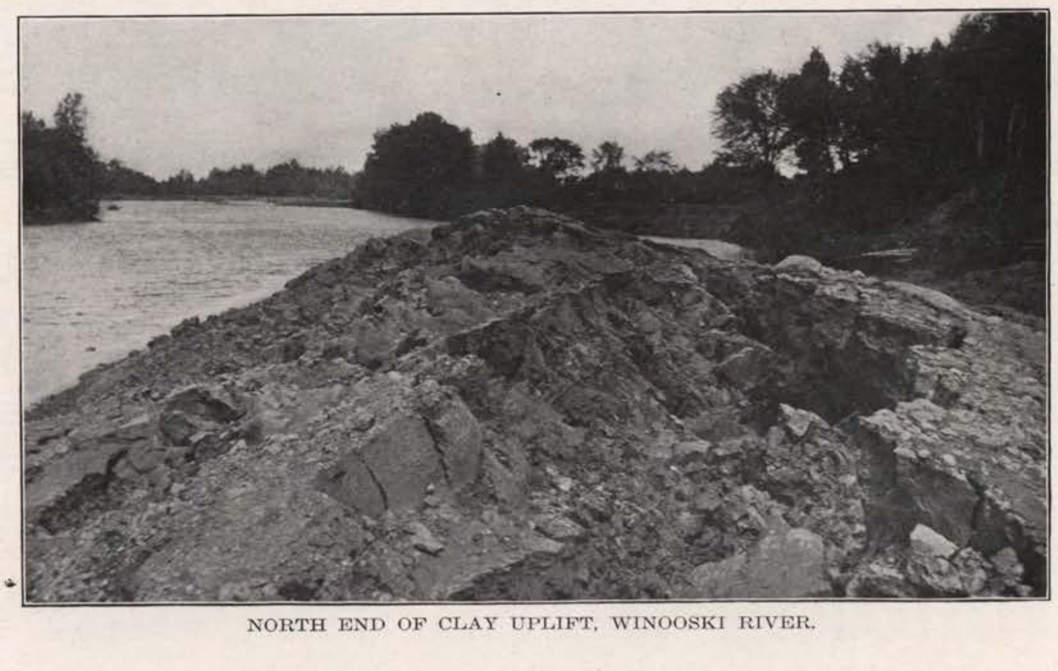
The explanation seems simple, there is a heavy bank of sand resting on a bed of stiff clay. This clay for many centuries had been stiff enough to sustain the mass above it, but at last through some change of conditions, it became softer, probably because water found its way through it and at last it gave way beneath the great weight above it. The top of the clay was stiffer than

PLATE LIX.



CLAY UPLIFT IN WINOOSKI RIVER.

PLATE LX.



NORTH END OF CLAY UPLIFT, WINOOSKI RIVER.

that below so that when it gave way the clay immediately beneath the sand bank was squeezed out and moved in the only possible direction under the existing conditions towards the river and under the top layer which formed the river bottom lifting this as an elastic covering into the rounded elevation seen and filling in below as the upper layer rose of course letting the sand cliff down as it went out. That is the soft clay was not pushed into the river as under other conditions it might have been, but pushed under the stiff clay bottom over which the river flowed and raised it without breaking the tough top layer.

Late in the fall of 1915, more than a year after the mound was formed, I compared it with figures taken the day after the slide occurred and was surprised to find how little change had taken place in the mound. It was a little smaller, a little less even over the surface, but it still presented nearly the appearance seen in Plate C.

BURLINGTON.—There is much less variety in the rocks of Burlington than is to be found in most of the towns on our list. Most of the lake border is red or light Cambrian sandrock of which there is a large quarry in the south part of the city.

At Rock Point and Red Rock Point the red rock is displayed in strong headlands, the latter a hundred feet high and in Ethan Allen Park the lighter rock forms a lofty mass on which the stone tower is located. The Cambrian at the shore ends near the south shore of Shelburne Bay a short distance out on the point in Shelburne.

At Phelps Quarry, mentioned above, there is a most excellent opportunity to see the varied beddings of this rock along the north and south strike. In any considerable exposure of the red sandrock there is usually ample opportunity to note the different shades of red in different layers. These range from deep red to almost pure white. Some of the lighter layers are pure quartzite.

The great overthrust fault which has been mentioned is finely seen on the north side of Rock Point (Plate LXI) and this is the most southerly of the exposures of this fault where the Utica is plainly seen underlying the Lower Cambrian. Here as in several localities farther north, the black Utica several feet thick is in strong contrast with the light yellowish sandrock of the Cambrian.

Although so heavily exposed in places the sandrock is singularly destitute of fossils in this region. Ripple marks, sun cracks, worm borings and what appear to be casts of algae are abundant at Phelps Quarry, but not a single specimen of the trilobites common in the same rock in the northern exposures has ever been found in the Burlington rocks. Igneous disturbances must have been common after the close of, probably, Ordovician time as dikes of various sorts are numerous in this and the adjoining towns.

In the eastern part of the town there is a good deal of non-fossiliferous silicious limestone which may be Cambrian and probably is, but it may be the western edge of the Beekmantown.

On the west side of Muddy Brook near the Williston Road there is a little outcrop of Trenton, as shown by Trinucleus, etc. The Utica is only found within the limits of Burlington at the Rock Point overthrust, and more fully at Appletree Point north where it is well exposed.

SHELBURNE.—This town is covered by three large areas of Utica, Beekmantown and Cambrian. These extend through the town from north to south. Shelburne Point, except at the extreme eastern portion is entirely Utica and at the western end there is a most splendid showing of veining for several rods, the white calcite intersecting the black shale in every direction and the veins of all widths from a hair line to several inches are often crowded through the cliffs in greatest profusion.

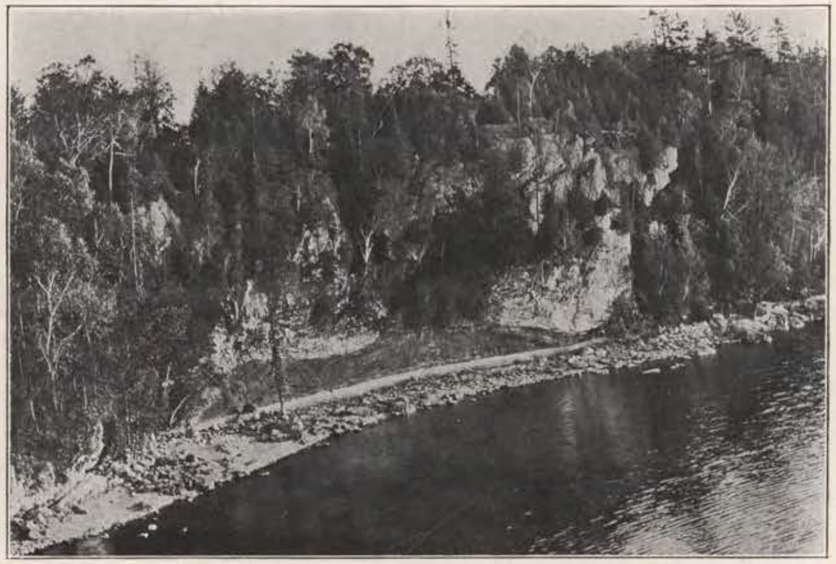
Rock Dunder, Juniper Island and the Four Brothers are also Utica, which through these masses at one time must have extended across the lake or nearly so. I have had occasion to allude to the presence of the calcite veins in the Utica several times, but nowhere are they so magnificently displayed as at the end of Shelburne Point and anyone wishing to study veining in rocks would do well to visit this locality.

The Shelburne shore south of the Point is wholly of the same shale. East from the lake there is a belt of red sandrock which in places rises in rugged masses and farther east is a great mass of what I have called Beekmantown limestone which covers more than half the township. No fossils have been found in any of these rocks so far as I know. The extraordinary number of dikes seen on Shelburne Point has been mentioned above.

CHARLOTTE.—In this town all of the Champlain Valley formations occur, though some are not found except in small patches. The Utica of the Shelburne shore continues through about half of that of Charlotte. However, this shore band of shale does not extend far east of the lake; at most not more than two miles and for the most part not more than one mile. There is besides a small band of Utica in the south part of the town starting a little south of Scott Pond along Lewis Creek across into North Ferrisburg.

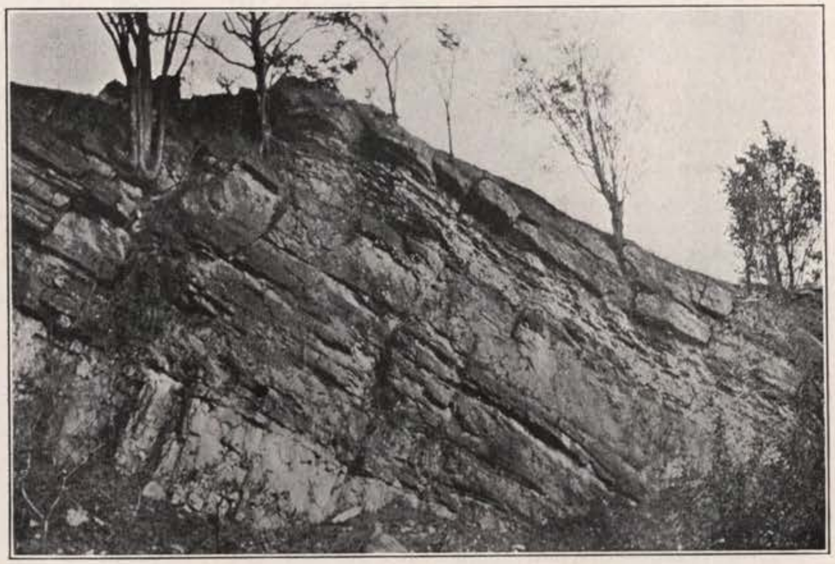
The Trenton is found at Cedar Beach and for rather more than a mile north beyond McNeil Point. A little east of this Trenton there is a small patch of Black River, but this is all of this rock in the town.

PLATE LXI.



PORTION OF OVERTHRUST, ROCK POINT.

PLATE LXII.



OUTCROP OF SILICIOUS LIMESTONE. SOUTHERN PART OF HINESBURG.

The rocks of the Chazy do not appear south of the Grand Isle exposures except a few insignificant bits in Milton and Colchester, until we reach the road south of the Charlotte station going to McNeil Point. Here is a small exposure and a somewhat larger on the road to Thompsons Point and a still larger at Ball Bay, where the southern part of the shore as far as the Cove is Chazy.

The Beekmantown is well displayed at Thompsons Point which is wholly of this rock, and as well for a mile and a half from the end of the Point. The gray silicious limestone is found abundantly in the eastern part of Charlotte (Plate LXII) while through the main part runs the great mass of red sandrock which rises into the higher elevations, as Mutton Hill, Pease Mountain and Mount Philo, the latter nearly a thousand feet high.

ADDISON COUNTY.

As we go south from Chittenden into Addison County we find better opportunities for studying the Ordovician rocks, but there is much less Cambrian. While there is little fossiliferous rock in the former county there is an abundance in the latter and all the Ordovician beds are shown as well as some of the Cambrian. As is almost universally the case the most fruitful collecting is near the lake. On the lake there are only Ordovician rocks, the Cambrian nowhere coming as far west as the lake.

The eastern part of Addison County is covered by the usual rocks of the Green Mountains, schists, gneiss and other metamorphic rocks. The Cambrian only appears in the northeastern part of the county in Monkton and New Haven.

The Beekmantown is seen well exposed along the lake shore as is the Trenton and to a much less extent the Black River as is the Chazy. This latter formation is found from the northern border along the lake south to Button Bay except the small area of Beekmantown at Fort Cassin. Then going south, there is a little Utica beyond which as far as the north line of Bridport the rock is Trenton, except where the shore is sand. In Bridport there is a stretch of Utica reaching about half way through the town when again Trenton comes out at the shore as far as Shoreham when Utica is again found until near Larabees Point Trenton is exposed. South of Shoreham in Orwell the rocks along shore are Beekmantown through the northern half beyond which the shore is drift as far as Benson.

In Benson in Rutland County the Beekmantown is constantly on shore and this continues on through West Haven.

Everywhere the surface of the Ordovician rocks is strongly glaciated, and the drift rests directly upon the Ordovician. Considering the towns of this county in detail we find that in Ferrisburg all the Ordovician formations are to be seen. At Ball Bay, the southern part of which is in this town good Chazy is found though the northern part is bordered by Beekmantown. On Long Point there is a little Black River and east of this in the ridge running through the town which is made of Trenton and Utica.

At Fort Cassin located on the north side of the mouth of Otter Creek, is an outcrop of Beekmantown which has become famous because of the number of new and fine species discovered there. Many of these were described by Whitfield in Bulletins of the American Museum of Natural History of New York and illustrated by fine plates some of which are reproduced in the Seventh Vermont Report.

Unfortunately for the geologist this exceedingly rich locality has been largely exhausted within the last few years. Moreover, a club house has been built on the ground and further exploration is objected to. More than sixty species have been collected here, many of them large cephalopods.

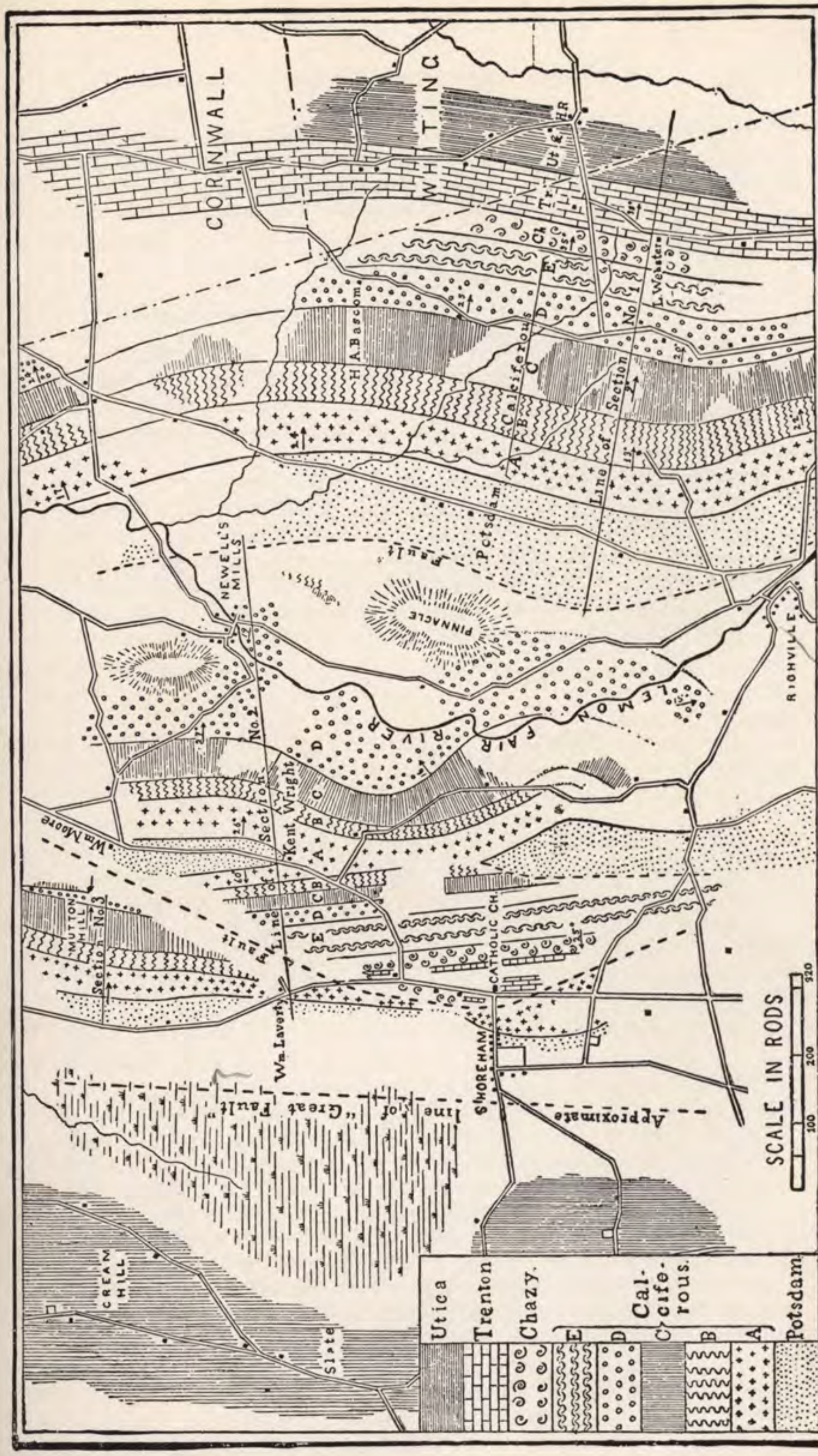
From the south bank of Otter Creek as far as Basin Harbor the Middle Chazy is the rock of the lake shore and on to Button Bay where there is Upper Chazy filled with Solenpora campacta.

An interesting mass of Black River forms the little island known as the *Scotch Bonnet* and the larger Button Bay island is also wholly of this rock. On the west side of Button Bay island is one of the finest examples of an old coral reef to be found anywhere. Here is a band some ~~two feet wide~~ filled with large specimens of Stromatocerium rugosum and Columnaria halli which have so weathered out that they are very conspicuous and present a most striking appearance, while the rock elsewhere affords usual fossils of this age. From Button Bay east the main road for some distance is bordered by the Black River. Farther east along the Little Otter and in its bed the Beekmantown is found. Not far from Ferrisburg Center there is a fault so that the Beekmantown is thrown over the Utica. There are also a few not very extensive localities where Trenton fossils can be obtained.

Panton.—Most of the surface of this town is covered by Champlain clays but at the lake shore Utica beds occur at the north and Trenton on the south. As Professor Seely remarks in the village one of the churches stands on the Black River and one on the Chazy. There is also Beekmantown in the town.

Addison.—Like Panton much of the surface of Addison is covered by drift, but there are numerous outcrops of Ordovician rock in town. On the lake shore the rocks are mostly Trenton, and many good examples of the life of this age can be found here. According to Seely there is a little Utica north of Norton Bay on the lake shore. At Chimney Point there is excellent collect-

PLATE LXIII.



EAST SHOREHAM, VT.

ing in the Trenton and Chazy and along the road north the Upper Chazy is crossed and farther on the Black River.

East of Dead Creek the Beekmantown is met and then the Chazy and Trenton and farther east the Cambrian near the Weybridge line.

Snake Mountain is in Addison and this is mainly a mass of Cambrian, but at the north end are Black River, Trenton and Utica beds and there is a great fault.

Bridport.—As in the preceding town all of the Ordovician beds are found in Bridport and in the northeast Cambrian.

Beginning on the lake shore at the north line of the town Utica appears near Port Franklin and is the only rock as far as the ferry. South of this are the Black River and Chazy and to the east a strip of Trenton which runs from the north through the town. East of this is Utica and then a narrow belt of Trenton and finally Cambrian. Seely says "In the northeast of the town is repeated on a small scale the rock condition found at Snake Mountain, the Beekmantown very near the northeast border and farther south and east a rapid succession of the Utica, Trenton, Black River and Chazy, then follows the Cambrian."

Shoreham.—Probably no town in the Champlain Valley affords the paleontologist as attractive a field for work as Shoreham, at least so far as Ordovician rocks are to be studied. This is partly because of the varied outcrops in the town and partly because Brainerd and Seely have made careful study of the rocks and have published the results of their work so that there is an excellent guide ready for any who wish to use it.

An examination of Brainerd and Seely's map which is here copied (Plate LXIII) Vermont Geological Report, will make it plain that the region presents much of interest to the geologist.

In most of these towns the most easily studied and interesting beds are on the lake shore, but here they are away from the lake in the interior of the town. On the lake shore the beds are much as they are in Bridport, that is, Utica on the north and Trenton on the south with clays coming to the shore for more than half the shore line.

Of these rocks on the shore those at Larrabees are most easily examined. Here one finds at the bottom of the series the Beekmantown, then the Black River followed by the Trenton, the Chazy being absent. Formerly the Black River limestone was quarried a little south of the point and worked for black marble for some years.

Passing east from the lake there is a large space entirely covered by drift after which comes a belt of Utica which extends from the north line two-thirds of the distance to the south line.

East of Cream Hill the Upper Cambrian is found and there are also all the Ordovician beds. "At the east of the Catholic

Church follow the Trenton, Black River, Chazy and the various divisions of the Beekmantown.

Beginning east of the Pinnacle which is itself Beekmantown they follow Potsdam and all the divisions, A, B, C, D, E, of the Beekmantown, then Chazy, a skip of the Black River, then Trenton and Utica reaching over and past the border of Whiting." Seely.

The rocks near Chevetts have afforded the best example of Halls fossil Cryptozoon ever observed.

ORWELL.—Here there is a large mass of Beekmantown along the lake front which rises into Mount Independence. There is also Chazy and also Trenton, but they are less typical and more altered than north.

VERGENNES.—The area of this city is small and not of great geological importance. Near the Reform School there is a small quarry of Black River. From its entrance into the lake Otter Creek is a sluggish deep-flowing stream with clay banks only a very little rock showing throughout its course as far as the falls at Vergennes.

Here, because of faulting the Beekmantown beds have been raised above those of the Utica and pushed over them.

Chazy and Trenton beds occur within the city limits, but for the most part they are covered.

WALTHAM.—There is not very much of geological interest in this town as all the formations which are found can be studied to better advantage elsewhere. The eastern half is Lower Cambrian, Buck Mountain, which is over a thousand feet high being of this stone. West of the middle of the town Ordovician strata occur from Chazy to Trenton.

Lignite has been found in well borings and this appears to be of the same kind as that well known from Brandon, but it nowhere comes to the surface.

MONKTON is largely occupied by Cambrian red sandrock and some quartzite. There is a little limestone in the southeastern corner which may also be Cambrian though I think it more probably Beekmantown.

There are extensive beds of kaolin in the north part of the town. On the western side of Hogback near the base there is a mass of red and white mottled stone containing much more lime than the rest of the rock of which the mountain is composed. This has been quarried and worked by the Vermont Marble Company and sold as their Rosaro.

NEW HAVEN is largely covered by Beekmantown beds though there is a tongue of Cambrian continued from Monktown into this town.

The Beekmantown is well seen in the New Haven River, the rapids and falls of which are caused by cliffs of this rock and elsewhere in New Haven there are outcrops of this limestone.

At New Haven Junction the Middlebury Lime Company quarry and burn the limestone. The Palmer ledge in the northern part of the town is somewhat unlike other limestone and Professor Seely has suggested that it may be Chazy.

BRISTOL.—The Beekmantown rocks of New Haven extend over much of the northern portion of Bristol while the whole of the eastern part is occupied by quartz and quartzite, high hills being formed of these rocks, which cause great unevenness in the surface.

Cambrian red sandrock is found in the northeast part of the town. The same absence of fossils alluded to time and again in speaking of the great mass of Beekmantown is found here.

A bed of iron oxide exists in the north part of Bristol but though many years ago worked for a time nothing has been done at the mine for a long time.

In Professor Fairchild's article, in this report, interesting facts as to the surface geology of Bristol and the region about the town will be found.

WEYBRIDGE.—Most of this town located west of the Lemon Fair is covered by Cambrian rocks. Immediately east of this stream is a mass of the Beekmantown which occupies half the area of the town and more and in the southeast corner there is Trenton limestone. Professor Seely remarks of the rocks of Weybridge that they "Have in the main been so metamorphosed that it is difficult to pronounce with confidence as to their formations."

A small belt of slate extends south into Cornwall and Whiting and thence into Rutland County where it is much worked.

MIDDLEBURY.—West of Otter Creek there is Trenton while east of this river the rock is largely Beekmantown.

The extreme east of the town is filled by metamorphic rocks and quartz. Some of the limestone has been metamorphosed into very good marble, but only one quarry, that of the Middlebury Marble Company is now worked. This is rather strange since the marble industry of Vermont really originated in Middlebury in 1806, though marble had been quarried and worked to some extent earlier than this in West Rutland and Dorset. As the falls of Otter Creek at Vergennes are caused by a fault and uplift so the falls at Middlebury are caused by another similar fault. Says Professor Seely, "The fault that has produced the falls at Middlebury village has marked the configuration of the vicinity. Going south it passes through the high school grounds leaving a depression, once very sharp, but now nearly filled and less noticeable as one follows its course. Where the rocks are exposed the line may be determined by the difference in the strata. To the north the water has worn an eddy and returning passes the somewhat uplifted contact of the Beekmantown and Trenton and has made a channel for itself over the latter."

CORNWALL.—In the north of this town beginning at the east side of the town there are Trenton beds and as one goes west, he will come to Utica, the Beekmantown, then Cambrian in the northwest corner. Other formations appear south of these until we find in the limits of Weybridge all the divisions of the Ordovician found in Western Vermont. Most of the above beds are in the north and south ridges.

WHITING.—The Utica exposure which begins in Weybridge and extends through Cornwall continues through Whiting and is greatly expanded in this town. Indeed it covers the greater part of the town. There is a very narrow belt of Trenton on each side of the Utica and according to Mr. Wing there is a little Chazy in the south part of town. This extends in increasing amount into Sudbury.

SALISBURY.—In this town there are Cambrian and quartz rocks in the east border, these rising in the heights, Bryant Mountain, Moosalamoo and Rattlesnake Hill. The Cambrian fossil Nothozoe was first found in this region in boulders, but while it apparently must have come from nearby ledge, diligent search has failed to reveal the source of the boulders here, but in similar rock in places in Bennington the fossil has been found. The rest of Salisbury is Beekmantown.

LEICESTER.—Here we find the arrangement of the rocks very much as in the preceding town, the Beekmantown covering most of the area and quartz in the eastern part. In Leicester the Beekmantown limestones are greatly folded and distributed. Differential folding of a most interesting character has now and then taken place and in Swiningtons Lime Quarry there are several "rolls" which have been formed as described in the Seventh Report, p. 352. One of these folds is over seven feet in diameter, nearly a hundred feet long and symmetrically cylindrical.

I have called all this limestone Beekmantown and I think it is, but as Professor Seely remarks, "The Leicester rocks of the south and west parts of the town are still demanding more careful study. Some are so metamorphosed that they approach marble. Some of the strata appear in general structure like Trenton. The fossils, brachiopods, found are not distinct enough to determine the horizon. The deposits of the lime quarries near Leicester Junction have been regarded as massive Chazy and yet the structure approaches the Beekmantown. As Beekmantown it may remain until new light is thrown upon the obscure problem."

BENSON.—The beds found north in Orwell are continued into Benson, a large part of the town being covered by Utica, but there is limestone along the lake which is probably all Beekmantown and between this and the Utica is a narrow band of Trenton. There is also some very good slate in Benson and formerly it was quarried.

WEST HAVEN the most southern of the towns of Addison County and of the lake towns resembles Benson in its geology and contains the same formations.

STARKSBORO, LINCOLN, RIPTON, GOSHEN are all mountain towns and the rocks are, as all the rocks of the immediate mountain region, highly metamorphic and crystalline. Unlike the other towns mentioned these have no stratified rocks. Going from east to west we find schists, gneiss, conglomerate and quartzites.

GRANVILLE and HANCOCK, also mountain towns, are mostly schist and gneiss.

As has been in several cases intimated, there is much work needed before a full understanding of the geology of western Vermont can be attained. There is not a single town in the above list in which interesting and scientifically valuable explorations and investigations cannot be carried on. Of course some towns will give much richer reward than others.

Especially I would recommend students of the Chazy to examine the numerous beds on the southern portion of Isle La Motte for there are here layers rich in fossils and so far as I can learn, they have never been thoroughly worked over.

In Shoreham, as the map plainly shows, there is a wide field for the study of nearly all the Ordovician beds, and other towns may well be studied minutely.

A good deal of general stratigraphic work has been done and frequent recognition of this will be noticed on the foregoing pages.

What is now most needed is thorough paleontological study of the fossil content of these beds, for this is by no means well known.

It may not be out of place to add for the encouragement of any prospective student, that I cannot think of a more delightful region so far as scenery and climate are concerned than western Vermont in summer, and this is especially true of the immediate vicinity of Lake Champlain.

THE TALC AND VERD ANTIQUE DEPOSITS OF VERMONT

E. C. Jacobs,
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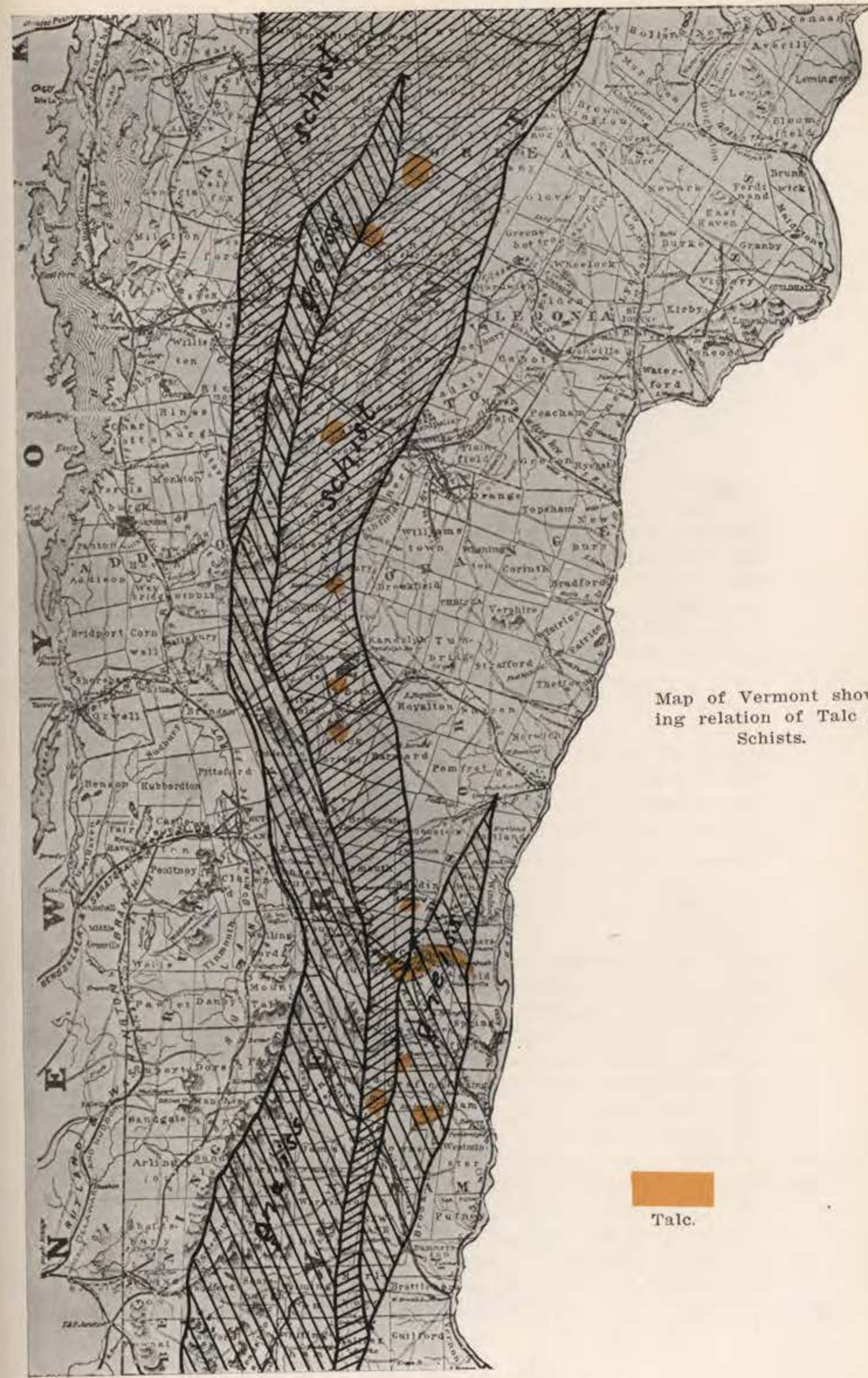
CONTENTS.

INTRODUCTION.

In the writer's first report on the talc deposits of the State,[1] he showed that these deposits occur in a broad belt of quartz-sericite schist which extends throughout Vermont from north to south and are a part of the great chain of metamorphic rocks constituting the Appalachian Mountains. In Vermont the talc belt occupies several parallel valleys in the eastern ranges of the Green Mountains. The map (Plate LXIV), reproduced from the first report, shows the location of the schist belt and of the gneiss which forms the crest of the range. On the smaller gneiss area in the southeastern part of the State are located the steatite, or soapstone, deposits. The talc occurrences are shown in yellow, but many new ones have been located since this map was made. The first report described the active talc mines both geologically and economically.

Geologically, it was seen that the talc occurs in very irregular lenses, or pods, lying concordantly with the schists, with their longest axes striking roughly north and south. A talc lens, where

[1] Ninth Report, Vermont State Geologist, 1914, pp. 382-429.



Map of Vermont showing relation of Talc to Schists.

Talc.

typically developed, was shown to consist of a large core of "grit" (a mixture of approximately half talc and half dolomite) which merges on both sides into talc. This talc varies in thickness from a fraction of an inch to ten feet or more. The talc, in turn, lies against a grayish black chloritic schist, called blackwall, which varies greatly in thickness and merges gradually into the country sericite schist. At Moretown the deposit is unique, for in place of the usual grit core there is a great mass of serpentine, whose transition into the bordering talc is clearly seen in thin sections of the rock. Pyrrhotite is found disseminated throughout the talc belt, while in the blackwall of the Chester deposit (Carlton quarry) good sized cubes of pyrite, and hornblende crystals occur. The presence of many igneous intrusions, altered to serpentine, throughout the talc belt was noted and the derivation of the talc from the serpentine discussed. No adequate explanation for the grit formation was reached.

Since the publication of the first report much new evidence has been found. The further development of the mines has furnished additional information, the study of the verd antique deposits of Roxbury has thrown new light on the problem, and Mr. Edward Wigglesworth's study of the serpentine outcrops in the State (presented elsewhere in this volume) has given a much better knowledge of the great chain of intrusions that is associated with the talc deposits. It may be noted here that the writer has been able to add information about several more serpentine occurrences to Mr. Wigglesworth's list. These will be noted in the course of this report. In the present article the development of the talc mines will first be taken up, then the verd antique deposits will be described, and finally such conclusions regarding the origin of talc, grit, serpentine, and verd antique will be given as the premises seem to warrant.

THE TALC DEPOSITS.

The talc, serpentine and verd antique deposits of the State lie in two roughly parallel broken chains, represented in their middle part, in the Rochester valley, on the west, and the Roxbury valley, on the east. On the western chain we have, south of Rochester, the Stockbridge talc and verd deposit (Greeley mine), the Plymouth, Ludlow, Andover, Windham, Dover, and Marlboro deposits of talc and serpentine, one or both. In the Rochester valley there are numerous occurrences of talc and serpentine, while to the north lie the talc and serpentine deposits of Warren, the talc deposit at the corner of the towns of Fayston, Waitsfield, and Moretown (International Mining Company's mine), the Moretown talc and serpentine (Magnesia Talc Company's mine), the Duxbury and Waterbury outcroppings of serpentine, the Cambridge deposit of talc and serpentine (Eastern Talc Company's prospect), the Johnson serpentine and talc deposits (American

Mineral Company's mines), the Waterville talc deposit (formerly operated by the American Mineral Company), and the Enosburg and Berkshire talc outcroppings (reported to the writer but not visited).

On the eastern chain there are, in the Roxbury valley, the great serpentine and verd antique intrusions (Barney Marble Company's quarries) which continue into Northfield. These are followed by the serpentine of Moretown and East Waterbury, where perhaps the two lines meet. No serpentine has come to the writer's knowledge in Stowe, Morrisville or Hyde Park but north of these towns lie the great serpentine and asbestos deposits of Eden and Lowell and the serpentine of Westfield (Hazen's Notch), Jay, and Troy. As far as known (the writer has not visited the last three localities) all these intrusions are in the foliations of the country schists, but just over the International Boundary, north of Troy, the Canadian Pacific Railroad cuts through several parallel ridges of serpentine which strike east and west, and therefore cut the schists and are probably later intrusions than the others.

South of Roxbury the eastern line of deposits includes the grit talc of East Granville (Eastern Talc Company's mines), the beds of steatite in Braintree and Bethel mentioned in Hitchcock's 1861 Report, the talc deposits of Reading (old Reading Talc and Asbestos Company's mine at Hammondville), the talc outcrop in Cavendish, and, finally, the grit talc deposit at Chester, which lies in the gneissic area and is followed by the steatite (soapstone) deposits of Chester, Grafton, and Athens.

All the best talc mines lie on the western chain. On the eastern, the talc is mostly of the grit variety, the serpentine is much more in evidence, and the best verd antique occurs.

ACTIVE TALC COMPANIES.

The five companies mentioned in the first report are still active, namely: the Vermont Talc Company, at Windham; the American Soapstone Finish Company, at Chester; the Eastern Talc Company, at Rochester and East Granville; the Magnesia Talc Company, at Moretown; and the American Mineral Company, at Johnson.

MINES AND PROSPECTS ON THE WESTERN CHAIN.

WINDHAM.

The Vermont Talc Company continues to operate its mine at Windham and has made considerable progress in opening up the deposit, which is a lens, over a hundred feet wide on the surface and of unknown length. The shaft is still bottomed at 70 feet, but the level has been extended northwards to 95 feet and southwards to a distance of 165 feet.

The company is now considering the use of diamond drills in order better to develop its mine and to discover possible new talc bodies. The mine is located on a low hill and an adit to penetrate this hill at its base and meet the workings is also under consideration. Such an adit would lessen hoisting charges and make the mine self draining down to the adit's level. The ten-mile haul to Chester Depot is the greatest handicap under which this company labors.

Several new talc prospects in this district have been reported to the writer. In Smokeshire, in the town of Chester, and in Ludlow there are said to be deposits of good talc. On the Herrick farm, in Andover, and on the King farm in Simonsville good outcrops are also noted. No talc development has yet been done on the Graves farm or on the Warren Rhodes farm, but it is reported that these deposits are held under option by some of the larger talc companies.

Since this is the soapstone region of the State, it may be mentioned that none of this material is being quarried in Vermont at the time. There is probably much good soapstone in the Davis quarry, in Chester, but no attempt is now being made to obtain it.

At Belmont, two and one-half miles from Mount Holly station a deposit of talc on the Ned Thomas farm was reported to the writer. This is near the summit of the mountain range and the country rock is gneiss. Thin sections of it show orthoclase and quartz, the former predominating, with muscovite, biotite, and some iron oxide developed between the grains. The deposit proved to consist of masses of tremolite enclosing considerable limestone in its laminations and lying in the folds of the gneiss, which is much contorted. A thin section shows the characteristic long needles of tremolite, enclosing calcite, with pyrite crystals here and there. No talc has been developed. The tremolite has evidently been derived from the limestone by the action of invading solutions. The formation suggests that at Gouveneur which there gives rise to the fibrous form of talc known as agalite. An opening has been made, twelve feet high and twenty-five feet long. The deposit probably has no economic value. In Belmont and Weston there are said to be good limestone deposits which were once burned for lime.

ROCHESTER.

In the writer's first report (p. 409 et seq.) it was shown that the talc deposits here lie in an irregular line, striking about north and south, on the western slope of Rochester Mountain, about two and one-half miles east of the White River. The Williams mine, the largest in the State, was shown to occupy the middle part of the line, while south of it the McPherson mine was being developed. The remaining parts of the line were made up of prospects which promised well. The Williams mine is represented by figure 3, which is the plan of the fourth level, and by figure 4, which is the profile of the mine, at the shaft.

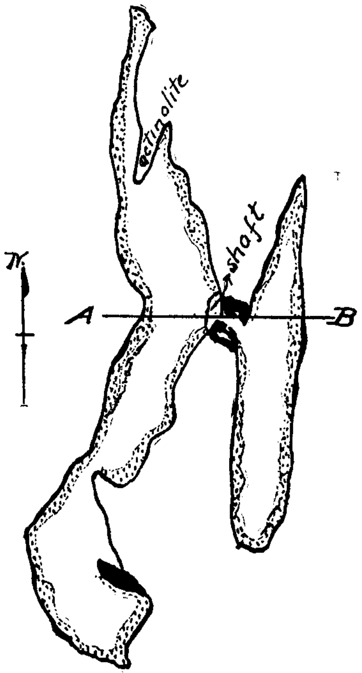


FIGURE 5.

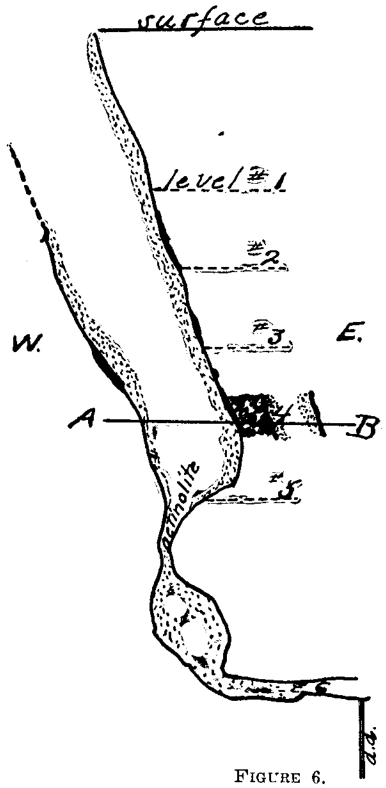


FIGURE 6.

This mine was shown to be opened up on a very irregular talc lens, or pod, some 300 feet long and 60 feet maximum width, lying in the foliations of the sericite schists and dipping with them at an angle of about 75 degrees to the eastward, down as far as the fifth level, where the dip changed sharply to the westward. The mine had a vertical depth of over 300 feet and was seen to consist of a great central core of grit-talc (a mixture of about half talc and half dolomite), which on either side merged gradually into talc (the stippled areas in the figures) of widely varying width. The talc was bounded on its outer side by a grayish black schist which microscopically resembled chlorite more than any other mineral and was so termed. This dark schist is called "blackwall" by the miners. It varies greatly in width, as shown in the figures, and merges gradually into the sericite of the country.

Since the time of the first report the Eastern Talc Company has done a large amount of development work, both by sinking the shaft to the sixth level and by extensive diamond drilling. At the time of the first report the company was sinking through the constricted area of actinolite shown at the 5th level in figure 6. Below this the lens again widened out, disclosing a lens of pure talc, showing no grit core. At the lower end of this pocket the deposit again turned to the eastward (level No. 6) to a point about 50 feet east of the shaft, where the direction again changed downward. A vertical drill hole sunk at this most easterly point was still in talc at a depth of 53 feet. Along the sixth level some grit was encountered. This sixth level is said by the mine captain to be 425 feet below the surface. This would make the total depth of the deposit at least 478 feet, vertically. Presumably the lower part of this great talc lens is, like the upper, concordant with the planes of schistosity of the country rock, but no examination of it has been possible by the writer. It seems very evident that the deposit has resulted from an injection of the country schists by a basic magma which has been forced upward by hydrostatic pressure into preexisting cavities. It is not known, as far as the writer is aware, whether the planes of schistosity of the country rock are also the bedding planes or not, though he believes that, in the schists of South Strafford, which are intruded by the chalcopyrite and pyrrhotite lenses, Weed has evidence that the bedding planes are distinct from the planes of schistosity. No such evidence has come to the writer's attention along the talc belt.

For such irregular intrusions R. A. Daly[1] has coined the name "chonolith" and he defines it as: "an igneous body (a) injected into dislocated rock of any kind, stratified or not; (b) of shape and relations irregular in the sense that they are not those of a true dike, vein, sheet, laccolith, bysmalith, or neck; and (c) composed of magma passively squeezed into a subterranean orogenic chamber or actively forcing apart the country rocks." The observed relationships of this lens do not seem to violate any of the provisions of this definition and therefore the Williams lens will provisionally be called a chonolith. This is the only talc lens in the State which has been so fully exposed, but from what is known of the others, it seems quite probable that they all belong to the same class of intrusions.

If the magma filled preexisting cavities, these cavities were probably formed in the Green Mountain folding, which came at the close of the Ordovician, or else by subsequent faulting, evidence of which is at hand.

In carrying on their exploratory work the Eastern Talc Company bored a diamond drill hole eastward from the fourth level

[1] Igneous Rocks and Their Origin, McGraw-Hill.

of the Williams mine, just south of the shaft. For 16 feet the hole was in blackwall, which included some sericite schist, when a new talc lens was encountered. (Shown on the right hand side of figure 5). This new lens has proved to be some 30 feet wide and 160 feet long. It possesses the usual relationships as to grit, talc, and blackwall. The talc averages about three feet in thickness, with a maximum of 20 feet. The vertical dimension is unknown, though a "raise" has been driven for a distance of 75 feet. This lens does not outcrop on the surface. The talc and grit are being hoisted from the main shaft of the old mine. It is not known how far, north and south, the black wall between the two lenses extends; nor whether we have here two independent lenses or one large lens with an offshoot.

On the next prospect, 700 feet south of Williams, number 5 mine is being developed. This proves to be a large independent lens over 400 feet long, in which two levels have been driven, opening up the deposit to a depth of over a hundred feet. The talc is of excellent quality.

From the prospect northeast of Williams some good talc has been taken. At the surface the walls are deeply grooved and rounded, perhaps by glacial action.

Very little serpentine has been found, in the past, in the immediate vicinity of the Williams Mine, the nearest outcropping being at Cushmans Hill, half a mile north. Recently, however, an outcrop lying east of number 5 mine has developed into a verd antique deposit. The shaft on this lens is down fifty-seven feet and discloses a mass of serpentine veined with dolomite (verd antique), chrysotile, talc, and blackwall. The significance of this formation will be discussed later.

The McPherson mine, seven-tenths of a mile southwest of Williams is now down thirty-five feet below the fourth level and extends 140 feet north and south. At this depth it is reported that the foot and hanging walls have come together—or that, in mining parlance, the mine has been "bottomed." This would seem to impeach the theory of igneous intrusions as the source of the talc, but it is to be remembered that in the mountains there has taken place a good deal of faulting, which may well have cut off the bottom of the lens. The only other talc mine whose bottom has apparently been reached is the old working at Johnson.

Extensive diamond drilling is being carried on in the neighborhood and it is safe to say that the mines of this region will continue to produce talc for many years to come.

Cushmans Hill was shown in the first report to be made up of a mass of serpentine containing disseminated octahedrons of magnetite and crossed by one or two dikes. The serpentine is veined with dolomite, in places, and some talc is found on its eastern side.

A number of other deposits of talc and serpentine have been reported, north of the Williams mine, of which two have been visited by the writer. Four miles north and two and a quarter miles west of Williams, on the farm of Mr. A. E. Goodno, there is a large deposit outcropping over an acre or more of ground. The general strike of the mass is north, 15 degrees west. The serpentine is greenish gray in color and is typically weathered and furrowed. Some shear fiber (picrolite) has been developed but no dolomitic veining is seen. In places the serpentine has been superficially altered to talc. Southeast of the serpentine mass, near the road, diamond drilling has disclosed the presence of a large mass of talc. This deposit is held under option by the Eastern Talc Company and will no doubt be developed in time.

A quarter of a mile farther north, on the farm of Mr. Arthur Brooks (the old Adams Jackson farm) there is another large outcropping of serpentine and talc. The serpentine is in the form of a great mound over 800 feet long and 100 feet wide. It strikes five degrees west of north. Much of the serpentine is veined with brown dolomite and talc has been developed here and there. The talc is of course much discolored and it includes rhombs of dolomite. As is usually the case in serpentine deposits (as pointed out by Wigglesworth) the surrounding ground is boggy, since the serpentine resists weathering more successfully than does the surrounding schists. This deposit has not been prospected but surface indications are promising. The serpentine is not veined and so of course has no commercial value, though it polishes to a very handsome stone.

There are also reported outcroppings of talc or serpentine on the western base of Mt. Cushman, on the farms of Mr. George Newton and Mr. Amos Stone.

In Stockbridge, five miles south of the Williams mine, the Greeley Mine was operated for several years by the Eastern Talc Company. The material mined was a low grade grit talc, in which large masses of green foliated talc were found, together with some small amounts of chalcopyrite. As the mine was developed the talc gave way to verd antique. The deposit is not now being worked.

It is thus seen that the Rochester valley is exceedingly rich in talc deposits. There are probably many other talc bodies yet to be discovered.

GENERAL TOPOGRAPHY NORTH OF ROCHESTER.

North from Rochester the White River valley continues through the towns of Hancock and Granville and into Warren, where lies the watershed between the White River, which flows southeasterly into the Connecticut, and the Mad River, which flows northerly into the Winooski, at Middlesex. In Granville the valley grows very narrow and has a beautiful waterfall (Moss Glen Falls) entering it from its western slope. The White River brooks disappear and the upper tributaries of the Mad River are seen. The valley gradually widens into the broad, fertile farm lands of Warren and then, in the northern part of that town again contracts. It is extremely probable that in Pleistocene times the Mad River reversed its course and flowed southerly into the White River; for in North Warren there is a great moraine of sand and gravel, thirty or forty feet high, which marks a resting place of the ice sheet on its retreat northward. The Mad River has now cut its channel through the moraine but formerly, while the ice lay in the valley, the river's northern course must have been blocked thus causing it to flow southward. There is a corresponding moraine on the other side of Warren Mountain, in the Roxbury valley, a mile or two north of the watershed at the Roxbury railroad station. This moraine probably caused the present Dog River, a tributary of the Winooski, to flow south into the Third Branch of the White River.

TALC AND SERPENTINE.

The next outcrop north of Rochester and in the same chain of deposits lies in Warren, on Mr. Edgar Towne's farm, which is on the road from Warren to Granville. Here there is a small prospect of talc which has been opened up for a length of twenty feet. At the surface the talc is full of actinolite needles. The deposit is probably not extensive.

Further north, beyond the four corners and just west of the road to Waitsfield, there are other occurrences of serpentine and talc. On the line between the farms of Mr. P. B. Daniels and Mr. H. W. Brooks there are two small hummocks of serpentine, one 35 by 15 feet and the other 60 by 20 feet, both striking a little east of north. They are ash gray in color and very compact in structure. Just west of them there is an irregular outcrop of serpentine, probably 225 feet long and 50 feet wide, with a good deal of talc developed in places. This outcrop is worthy of investigation for its talc possibilities.

In the northern part of the town of Warren, but just south of the village, there is the largest serpentine outcrop in this region. It lies on the land of Mr. L. W. Freeman and Mr. U. G. Austin and consists of a great ledge of serpentine rising about 60 feet above the surrounding country and striking north, forty degrees east (magnetic). It is 300 or 400 feet long and about 60 feet wide. The land east of it is swampy. The serpentine lies in the planes of schistosity of the country rock, as usual. The rock is typically weathered and the abundant veining of dolomite classes it as verd antique. It is unfortunate that remoteness from the railroad (the nearest station is seven miles away, over the

mountain, at Roxbury) will probably prohibit its ever being quarried for verd. A few rods west of the serpentine ledge is the moraine before referred to. In the neighborhood are found some small boulders of lower Cambrian limestone (Winooski marble) which have evidently been brought by the ice many miles from the north.

The next known talc deposit, northward from Warren, lies at the corner of Fayston, Waitsfield and Moretown, on the J. C. Bisbee farm. As stated in the first report the deposit was opened up and worked to some extent by the International Mining Co. The plant has remained idle for years, although there seems to be a very large amount of good talc available. The haulage charge to Middlesex station, seven miles away, may have been too heavy. In all mining enterprises the question of transportation is of exceeding importance and several mining companies in the State seem to have overlooked this fact, to their cost. The margin of profit in talc mining, in Vermont at least, is very small, owing to a considerable degree to sharp competition among the companies; so that haulage charges should be considered very carefully before embarking upon mining enterprises.

MORETOWN.

In the previous report it was shown that the deposit here consists of a great mass of serpentine, about 125 feet wide and of unknown length, and striking north, 20 degrees east (the average strike is said to be 15 degrees). The lens lies in a hillside with its northern end exposed on one of the benches of the Winooski River, not quite two miles from Waterbury. The talc vein is found on the west border of the serpentine mass and is bounded by the inevitable blackwall, which merges into the country schist. The deposit is unique in that it has, in place of the usual grit core, a core of serpentine, while residual serpentine "cobblestones" and nodules are embedded in the talc. Microscopic study shows the gradual alteration of antigorite to talc, as the talc vein is approached. The mine is opened up by two adits, one above the other, which show the existence of a body of talc at least 1,000 feet on the strike, not less than 200 feet deep, and from 8 to 30 feet wide. See figure 7.

Since the date of the above report the Magnesia Talc Company has done extensive development work and has greatly enlarged the size and grinding capacity of the mill. The cross section of the whole mass of serpentine and talc has been shown, by means of dip measurements taken on the east wall at the surface, and in the lower adit, to have an asymmetrical V-shape, the west leg averaging 85 degrees dip to the eastward (though in places it is practically vertical) and the east leg dipping from 45 to 55 degrees to the westward. The result is that in the lower adit the

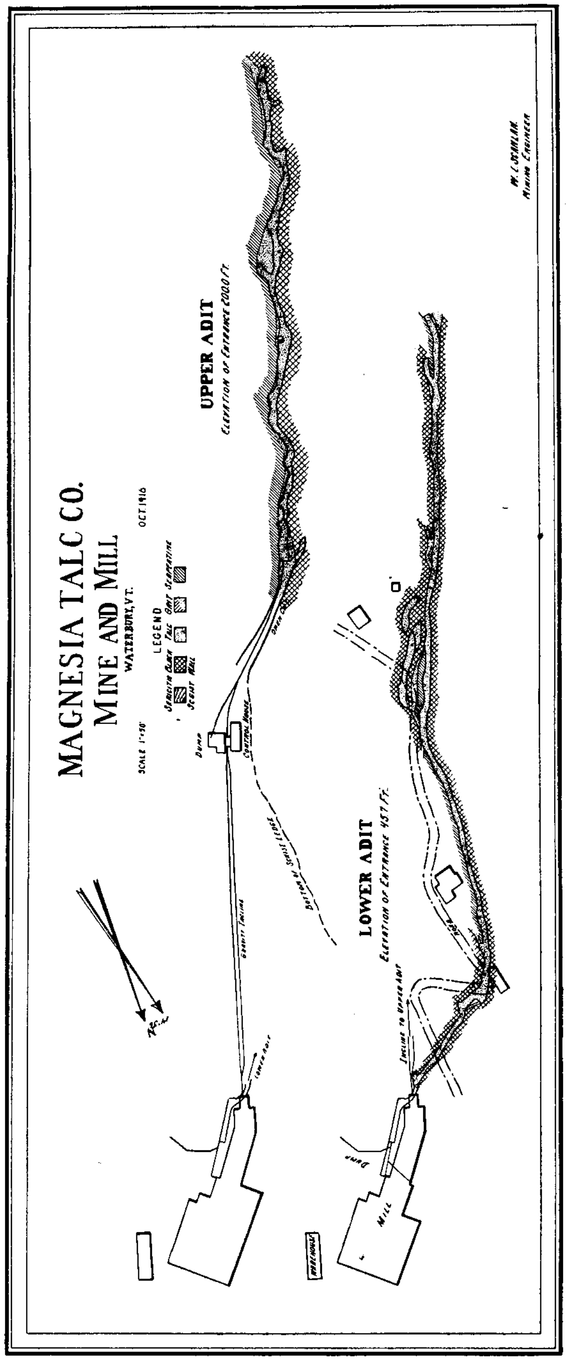


FIGURE 7

serpentine has narrowed to 27 feet in width, and cross cutting from the west wall eastward has disclosed an easterly vein of talc, as was to be expected. This vein is bordered on its outer edge by blackwall, of course, merging gradually into the country schist.

The two adits have penetrated the talc body for about 1,400 feet, and shown it to be persistent in quantity and improved in quality. The lens also appears to increase in width as tunneling progresses. Grit talc is not at all the predominant material here, as it is at the other mines; still pockets are met in the talc, here and there, nearest the serpentine, the largest being 3 to 4 feet thick, 30 feet on the strike, and perhaps the same distance in vertical dimension. Furthermore, as regards this introduction of carbonate, there are areas of the serpentine in the lower adit which show more or less veining and so approach a verd antique composition.

The serpentine and talc in North Waterbury, on the farm of Mr. Zene Anderson (the old Clough farm) has been fully described by Wigglesworth.

Hitchcock, in his 1861 Report on the Geology of Vermont, speaks of steatite beds in Stowe, but the present generation seems to know nothing of them. They are evidently of exceedingly low grade material, for the writer has found the inhabitants of the towns which he has visited very well informed regarding mineral occurrences in their neighborhood.

JOHNSON.

In Johnson, as was shown in the first report, the American Mineral Company practically exhausted the small talc lens, near the railroad, on which it had been working for several years and turned its attention to the mineral lands which it had acquired in the eastern part of the town, some four miles away, maintaining its mill, however, at the old site. The new deposits were seen to consist of two large lenses, in line, striking north, ten degrees east and dipping from vertically to 55 degrees westward. The deposit is quite similar to that on which the Williams mine is located, consisting of a central core of grit, flanked by talc, which, in turn, is bounded by blackwall. At the present time only number one mine (opened on the south lens) is being worked. The deposit has been traced on the surface for a distance of, roughly, half a mile, while the outcropping blackwalls are 187 feet apart. This is the largest surface showing of any talc lens yet discovered. The shaft has been sunk in the east wall (the foot wall) to the second level, eighty feet below the surface. Levels have been driven 600 feet north of the shaft and 500 feet south. A cross cut has been driven westward through the grit for a distance of 190 feet without striking the west talc zone, showing that the lens has increased in thickness with increasing depth.

This mine is remarkable for the amount of non-talcose material found in the talc and grit. The blackwall, which borders the talc and merges into the country rock, is grayish black, has a hardness of 1, in the mineralogical scale, and is well laminated. Its mineral constituent is chlorite. But in the talc and grit there is a great pillar, at the shaft (and considerable masses are scattered through the mine), of a dove colored substance, which can be scratched by the finger nail (hardness of 1) and is of a massive structure. Microscopically it is seen to consist of some member of the chlorite family not yet identified. The talc cleaves sharply from it and no genetic relation is seen.

That serpentine is present near the talc lens is shown on the surface where, 400 feet south of the shaft (and therefore in contact with the talc, since the second level extends 500 feet south of the shaft), there is a mound of serpentine veined with dolomite, hence verd antique. Other outcroppings of serpentine also occur.

As pointed out in the first report, much faulting is in evidence in the mine and slickensiding is remarkable in the northern lens (number 2 mine) where the blackwall is polished to the smoothness of window glass.

The talc and grit of this region are the best in the State, both as regards color and low iron content.

There are several other talc deposits in Johnson. North of the American Mineral Company's mine, on the Shattuck farm, there is a good outcrop on which the Eastern Talc Company holds an option. On the Soule farm, half a mile west of the mine, another outcrop is reported, while to the south, on the Ruggles farm, there is a third outcrop. There are thus indicated large deposits of talc in this region and of the best quality. A much larger tonnage could easily be obtained on the investment of larger capital.

CAMBRIDGE.

Five miles west of Johnson, and two and a half east of Cambridge Junction, there has long been known an outcropping of talc on the old Bradbury Fullington farm, just south of the St. Johnsbury and Lake Champlain Railroad. The farm is now owned by Mr. A. F. Rousseau who has disposed of the mineral rights to the Eastern Talc Company. This company has opened up the deposit by an adit driven parallel to the long axis of the lens for a distance of 145 feet. The lens is found to strike about north and south and dips about 45 degrees to the westward. The usual relationships of talc and grit obtain here. Diamond drill cores have shown a very large amount of talc of excellent quality.

Farther north, the Waterville deposit has not been reopened. The reported outcrops in Berkshire and Enosburg have not been

visited. These localities are too remote from the railroads to become commercial possibilities as talc producers.

THE TALC AND SERPENTINE ON THE EASTERN CHAIN.

On the eastern chain of talc deposits, as mentioned before, the mineral is of a much inferior quality, being a low grade grit talc.

CHESTER.

The American Soapstone Finish Company continues to operate the Carlton quarry near Chester village. This quarry is really in the gneiss belt and one of its walls is bounded by gneiss, with which amphibolite is associated. In the last report it was seen that the blackwalls of this quarry (for the talc is obtained by open cutting) were dark green, very lustrous, and contained large cubes of pyrite and also crystallized hornblende. This same variety of chlorite also surrounds the steatite lenses of the Davis soapstone quarry, a few miles away. The talc in the Carlton quarry is a mongrel material but it grinds well and quite a number of uses for it have been found by the company.

There is said to be talc in Cavendish, at Gassett's Station. Farther north the serpentine has been described by Mr. Wigglesworth.

The Reading Talc & Asbestos Mine at Hammondville is still idle.

EAST GRANVILLE.

The next talc mine on this chain is located at East Granville, where the Eastern Talc Company began its mining and milling operations. The first report showed that this mine is located on a chain of lenses varying from 50 to 400 feet in length and from 15 to 50 feet in width. The deposit is opened by two adits, one above the other, and the talc is sent down by an aerial tramway to the mill, beside the Central Vermont tracks. The mine has been extensively developed and will continue to yield its product for many years to come.

Farther up the valley, just north of the East Granville-Roxbury line, the Eastern Talc Company, some years ago, opened up a small talc deposit just west of the highway. A small amount of excavating was done but, for some reason, operations were discontinued.

* * * * * *

This is the last talc mine on the eastern chain. North of East Granville one comes to a region of serpentine lenses, many of which are veined with dolomite, furnishing the so-called green marble, which is known scientifically as verd antique, or ophicalcite. The study of these deposits has thrown a good deal of light on the talc problem and therefore they will be described in detail—

and also because they are very worthy of study on their own account. There are only a few localities in the country possessing verd deposits and the Vermont stone has come to be used extensively for interior paneling and other purposes.

THE VERMONT VERD ANTIQUE DEPOSITS.

Definitions and Historical Note.

By "verd antique" is meant serpentine veined with marble, either calcite or dolomite. This veining, crossing the dark green rock in every direction, in delicate traceries or broad splashes, gives it the appearance of a brecciated mass which, when polished, produces a beautiful appearance. Other minerals, talc, chromite, magnetite, also occur but these are accessory. To this rock Brongniart gave the name ophicalcite.

The rock which we now call verd antique (and which the ancients classified as a porphyry) was one of the highly prized decorative stones of antiquity, being obtained from Egyptian and Grecian quarries. References to it, however, are by no means common. Among the hard rocks the ancients distinguished syenite, granite ("granum"), basalt ("basanites"), serpentine ("ophites"), and porphyry, without having much appreciation of their mineralogy[1] or texture. Of the porphyries they quarried three varieties: red, green, and mixed red and green. Hugo Blümner[2] says there is no doubt that the green porphyry is identical with the green Lacedemonian stone of Krokea and the Thessalonian green marble of Atrax, which were described by Pausanius in the second century, A. D., and are the modern verd antique.

The Egyptian quarries were at Cynopolis, on the Nile, but no further reference to them has been found.

Pliny[3] speaks of the Grecian stone but is aware of no Italian sources.

Paulus Silentiarius, writing in the sixth century, A. D., gives the locations of the Grecian quarries, the chief uses of the stone, and describes notable objects carved from it. Most of the information available at present is based on his writings.[4]

Isidor of Seville, in the sixth and seventh centuries, speaks of the Lacedemonian stone as being "scattered under the earth"—probably from its occurrence as waterworn boulders.

In Greece the most famous quarries were at Atrax, Thessaly, and in Krokea (Crocea), on the south coast of Laconia. Paulus describes the Atrax marble as of three varieties: an emerald green, a bluish green, and a black and white. Of these the last

[1] Werner, in the 18th Century, gave to granite and syenite their present meaning.
[2] Gewerbe und Kunste bei Griechen und Römern.
[3] Natural History.
[4] Th. C. S. Tafel, in Abhandlungen der Bayerischen Akademié der Wissenschaft, 1836.

named is most suggestive of the modern verd. He states that the green columns of the Mosque of St. Sophia, Byzantium, and in the Church of St. Sophia, built by Justinian in Salonika, as well as the sarcophagi and decorations in the palaces of the Byzantine emperors were made of this Thessalonian stone. Atrax marble seems to have been used from the fifth to the tenth centuries, after which it was discontinued, perhaps owing to the decline in popularity of the stone.

W. G. Rennek[1] states that the Thessalonian deposits were rediscovered by a Mr. W. Bradley in 1889, no less than ten ancient quarries being found. In 1896 the Verde Antico Marble Company was formed and it has exported verd to this country. Verd is also exported from the island of Tinos.

The Crocean green marble was much less famous. It was hard to work and consisted, in part at least, of waterworn boulders. It took a fine polish, however, and was used as a paneling in temples, baths, and springs; while a statue of Zeus, carved from this material, stood at the entrance to the village of Crocea.

The verd marble is seen in Roman buildings and some extremely rare greens are found in the museums of the Vatican and the Louvre.

Our word verde antique is from the Italian "verde antico" (ancient green), which in old French becomes "verd antique"; in modern, "vert antique."

The Italian verd antique quarries were discovered, apparently, centuries later than the Grecian. From them come "Verde de Prato (near Florence); "Verde de Pegli"; and "Verde de Genova", which in this country is known as "Genoa Green." From the Cottian Alps, in eastern France, comes the "Alps Green."

Verd antique occurs in Cornwall, Ireland (Counties Galway, Donegal, and Sligo), and Banffshire, Scotland. In the United States verd is found in Georgia, Maryland, Pennsylvania (Easton[2]), Michigan, California, Westfield, Mass., and Roxbury, Vermont. The Roxbury verd is probably the best and most used of the domestic stone in this country.

LOCATION.

These deposits lie in the Roxbury valley, which is seven miles east of the valley running through Warren, West Granville, Hancock, Rochester, etc. Warren Mountain, a continuation of the Rochester Mountain, separates Roxbury from Warren. At the Central Vermont station at Roxbury, 1,009 feet above sea level, is the divide for this valley. From the west slope a brook flows down and turns northwards into the Dog River, a tributary of the Winooski; while from the east slope another brook flows into

[1] Marble and Marble Working, Van Nostrand.
[2] The trade name is "Sylvan Green."

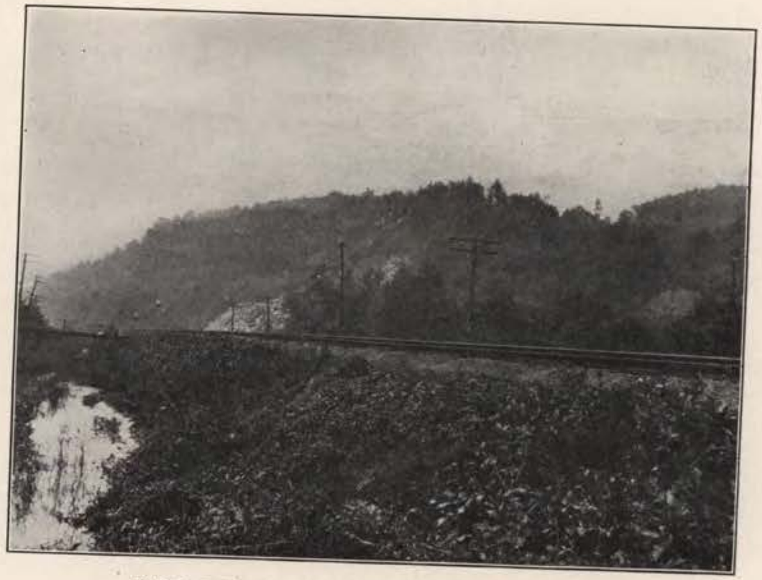
the valley and turns southward into the Third Branch of the White River, a tributary of the Connecticut. The valley is narrow for the most past and very sinuous. North of Roxbury, as already stated, it has been dammed by a moraine through which the Dog River has now cut its course. The country rock of the whole region is quartz sericite schist (fully described in the first report), whose strike is north 30 degrees east (magnetic). It may be stated here in regard to compass bearings, that the declination of the magnetic needle, as given in the U. S. topographical sheets, is, at the present time, 13½ degrees west of the true north. All strikes in this article are magnetic and should be corrected accordingly for true directions. The schists dip at high angles, 75 to 85 degrees, to the eastward. The intrusives which gave rise to the serpentine always conform to the planes of schistosity.

In the Roxbury valley verd antique has been quarried intermittently since about 1853. The Central Vermont Railroad was built in 1848 and it is very likely that blasting for its roadbed revealed the commercial possibilities of the rock. The American Verd Antique Company began quarrying, a few rods west of the railroad, and its old quarry (number 1) is still producing excellent stock. But operations were suspended about 1858 and the quarry lay idle till the early nineties, when first Mr. John M. Baxter, of Rutland, and later the Barney Marble Company, of Swanton, acquired the property. The Vermont Marble Company assumed control in 1902 and has opened up many new quarries and carried on operations very energetically, under the superintendence of Mr. J. B. Kidder.

THE FORMATION.

Five miles north of East Granville, and one mile south of the Roxbury station, the valley widens and is divided into two parts by a ridge which rises gradually from the valley floor to a maximum height of perhaps 200 feet and extends northwards for miles. The east branch is the trunk valley through which the railroad and highway pass; the west branch is short and, after extending for a mile or two, merges into the eastern slope of Warren Mountain. The ridge is somewhat forked at its southern part and it is in the east tine of this fork that the best quarries occur. The photograph (Plate LXV) shows the eastern slope of the ridge. In the right foreground is seen the old number 1 quarry, which is half a mile south of the railroad station, while to the left is seen the dump from number 2 quarry. The ridge is here about 160 feet above the track (barometric measurement) and 300 or 400 feet wide. It is composed of a great central core of a green schist, striking north, 30 degrees east, and nearly vertical. Near the margins of this core are found large lenses

PLATE LXV.



THE ROXBURY VERD ANTIQUE RIDGE.

of serpentine and verd antique conforming to the schistosity. The lenses thus lie in the green schist, which itself gradually merges into the sericitic country rock. This merging, however, is so gradual that for many yards traces of the chlorite are seen interlaminated with the sericite. This green schist has been studied and will be considered later. In places, by the highway which runs along at the base of the ridge for example, the sericite and chlorite have ben eroded away and great jointed blocks of serpentine and verd are seen. The ground at the base of the ridge is swampy, as is almost always the case around serpentine outcrops. East of the tracks the surface water has collected in a shallow basin, called Mud Pond, which empties into the Third Branch. There has been a good deal of gravity faulting along this ridge, the fault planes lying at right angles to the trend of the ridge. The south end of the ridge shown in the illustration has been cut off by this action and now shows an abrupt fault scarp, and this process is seen again north of the old number 1 quarry, shown at the right of the illustration. Farther north, opposite the station and again at the Tierney quarry, it looks as though whole sections of the ridge had been faulted downward. These breaks in the ridge are called locally "cross cutters" and roads are built through them. The north wall of the first mentioned "cross cutter" is vertical and over 20 feet high, while the south face of the fault is 60 or 70 feet away.

THE QUARRIES.

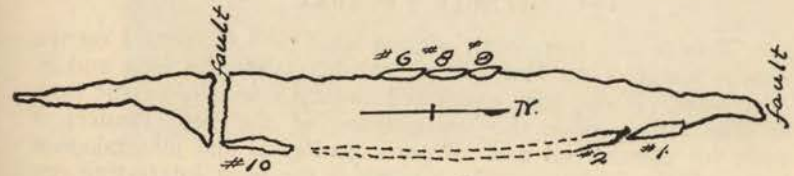


FIGURE 8.

The sketch (figure 6) shows the plan of the verd antique lenses which lie in either flank of the green schist ridge. The most important quarries are located on these lenses and are numbered in the order in which they were opened up (numbers 3, 4, 5, and 7 are some miles farther north and will be considered later).

No. 1 quarry, which is the largest, was begun about 1853. It is 100 feet long, 40 to 50 feet wide, 100 feet deep (below the valley floor), in the north end and 160 feet in the south end. The west side of the quarry rises 75 feet above the valley floor, practically vertically, and shows the green schist against which the verd lies. Between those two kinds of rock, in places, there is seen some development of talc and grit. On the east side of the quarry the verd is again bounded by green schist, which extends eastward and is lost under the waste rock. But a few rods farther east sericite schist appears. The verd lens narrows southward and probably overlaps lens number 2. Near the surface, at the south end, there is a mass of discolored talc. At the bottom of the quarry the verd has become so poor in quality that further quarrying has been abandoned. But in the southern part there remains much good rock which will last several years longer. From this quarry many thousand cubic feet of the finest verd antique have been taken.

This verd antique consists of a great mass of serpentine veined in every direction with dolomite, chrysotile, and some shear fiber (picrolite). It is for the most part very sound and polishes to a deep sea green stone veined with glistening white dolomite. Occasionally, however, the dolomite veining gives way to talc on picrolite which causes the rock to break and so renders it unfit for use.

Quarrying is done by means of steam drills and channeling machines. The stone is cut into blocks 8 x 3½ x 4½ feet and shipped to Swanton and Middlebury for dressing.

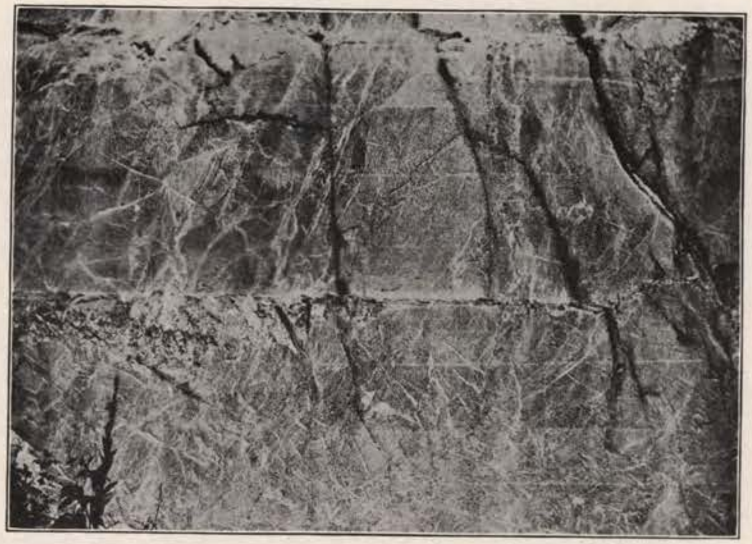
Going south towards number 2 quarry, one notes that the verd along the bottom of the ridge has been altered to talc to a depth of several inches. It is hard and impure but shows the change distinctly.

NUMBER 2 QUARRY.

This is 275 feet south of number 1 and is opened on the southern end of the lens. It is probably 1,500 feet long and 50 feet wide. It has been excavated about 15 feet below the floor of the valley, since the unsoundness of the verd renders it unfit for commercial use. From a geological and mineralogical point of view, however, this quarry is the most interesting one on the ridge. On the west the verd lies against the vertical green schist wall and here, where there has been movement, there is a shear zone of hard, fibrous chrysotile called picrolite. Here, as well as elsewhere about the ridge, one sees how the picrolite has been developed from the serpentine by shearing, pieces of the massive serpentine being found which have been pulled out into a stiff, fibrous mass—some such effect as is gotten by pulling out molasses candy when it is nearly cold.

The photograph (Plate LXVI) shows the north end of the quarry, which is verd. The fine white veining is typical of verd antique, while the large joints and fissures render such rock worthless for commercial uses. These fissures are filled with crystallized dolomite, in some places lenses two feet long and two inches wide being found; while in others shear fiber has de-

PLATE LXVI.



NORTH END OF VERD QUARRY, No. 2.

veloped. On the horizontal joint planes, particularly in the floor of the quarry, there are large tabular masses of crystallized dolomite, including beautiful green foliated talc and masses of soft, fine fibered, greenish gray picrolite which in places becomes nearly chrysotile. One specimen of this fiber measures 3 feet by 2 inches by 2 inches. The dolomite is often beautifully slickensided, showing clearly the shearing to which it has been subjected, and it *includes the shear fiber*. This fact and the evidence of thin sections of verd show conclusively that the verd owes its existence to the infiltering of carbonates to the cracks and crevices which are so characteristic of serpentine. The chief difference between the rock of this quarry and that of number 1 has resulted from the greater amount of movement of the rock masses. Hence number 1 quarry produces a sound rock with fine veining, while number 2 yields the worthless material shown in the illustration.

Regarding the carbonate which has filtered into the cracks and crystallized out, quite a number of writers on verd antique, including Edward Hitchcock,[1] describe this as magnesite (magnesium carbonate) but the following analysis of the Roxbury mineral shows it to be an average dolomite.

CaO,	30.63%
MgO,	21.20%
Fe_3O_4,	1.43%

The iron here represents the magnetite which all sections of serpentine show to be present.

The south end of the quarry is equally interesting. Here a section from the green schist west wall eastward shows the following sequence:

A sheared band of picrolite.
Fifty feet of verd antique.
Two feet of grit talc.
Six feet of talc.
Three and a half feet of picrolite.
Two feet of serpentine.
Three feet of hard, talcose schist.
At least thirty feet of the same green schist which forms the east wall. This green schist makes a sharp contact with the talcose schist on one side, and plunges beneath the surface soil on the other. Its contact with the sericite schist farther east could not be reached. No typical blackwall was seen in the section but pieces picked up on the dump prove its existence in the formation.

It thus appears that verd antique, picrolite, talc, and grit have been derived either from the serpentine itself or from the rock giving rise to the serpentine; the picrolite where shearing has taken place, the talc where metamorphic processes have attacked

[1] Report on the Geology of Vermont.

the parent rock, the grit and verd, where carbonate solutions have filtered in.

NUMBER 10 QUARRY.

Farther south, just at the fault which divides the ridge, is the newest opening, number 10. This has been in process of development since last fall and the stripping operations have revealed a large mass of first class verd. The quarry is 350 by 50 feet and is being opened from the top of the ridge. No new features of geological interest are seen here.

QUARRIES ON THE WEST SIDE OF THE RIDGE.

Here three quarries have been developed, numbers 6, 8, and 9. At number 6, the southernmost, some great masses of verd had fallen from the ridge, years ago, and these were the first to be cut. These quarries are over 100 feet long by about 50 feet wide, and are opened up on great lenses of verd which are about in line. Number 6 is the only one being worked at present. It is furnishing some excellent rock. The relationships of green schist, talc, grit, verd, etc., are about the same as on the east side except that here a sequence of grit, talc, blackwall, and sericite schist follow the verd. In number 8 some fifteen feet of talc and grit are developed next to the green schist core, and in number 9, about twelve inches of actinolite are found in a similar position.

It was noted that the ridge dividing the valley was forked near its southern end. Going west from the eastern turn, containing the quarries, one comes, in a few hundred yards, to the western turn. This is a ridge of the same green schist which forms on the west side, a nearly perpendicular wall, twenty or twenty-five feet high and contains no serpentine. Continuing westward, as one crosses the smaller valley and climbs the western slope, one notes that the green schist begins to have quartz inclusions and then to become interlaminated with sericite schist. This continues for some distance until finally, about half a mile west of the ridge, the green schist disappears and the typical quartz-sericite schist of the region replaces it.

SOUTH OF THE RIDGE.

Along the highway of the ridge, from Roxbury to East Granville, one notes great jointed blocks of serpentine, colored ash gray and covered with lichens. In places the serpentine is veined, forming antique,which shows that the product has depended upon the presence or absence of dolomite in solution. Farther south the serpentine and verd lie in from the road and the fault precipice appears. Farther still, and lying just east of the track, there is a small knoll which contains a body of verd 200 feet long and 50 feet wide. It lies just south of Mud Pond and is the most southerly lens thus far discovered in the Roxbury valley, although it is believed that other lenses occur. Beyond the knoll the green schist disappears for a time and sericite schist is seen.

Beyond the serpentine ridge, as has been said, the two small valleys become one and continue in a sinuous line to East Granville, Randolph, Bethel, etc., to the Connecticut. In the sericite country west there are ridges, here and there, on both sides of the valley, of the same green schist seen in the ridge. The first is noted in the east slope of the valley, opposite the Vermont State Fish Hatchery, where it is so fissile that it has been used for flag stones. Farther south the green schist appears in the west slope of the valley, by the roadside, and here, also, boulders of serpentine are seen beside the road, whither they have fallen from the valley slope. The foliage on the valley slopes is so dense that only a careful search could reveal the presence of serpentine in places. The strike of the green schist is about north, 20 degrees east, as before, while the dip is 80 to 85 degrees easterly.

OTHER VERD DEPOSITS.

As one walks along the ridge northwards from the group of quarries just described, one sees several more fault cliffs and, here and there, an outcrop of either serpentine or verd. The largest of these outcrops is half a mile north of number 1 quarry and west of the private house of Mrs. Spaulding. Here there is a very large mass of verd antique, bare of vegetation and well veined. An exploratory drill hole bored into this outcrop showed, from east to west, the following:

15 feet of serpentine.
5 feet of talc.
40 feet of verd.
00 feet of grit talc.

The drill hole did not reach the western boundary of the deposit. Magnetite octahedrons and iron oxide spot the serpentine and green schist is found on either side. It is to be noted that if the serpentine in the verd zone had been altered to talc, we should have the members of a typical talc deposit, save for the blackwall and it would not be surprising if this were also present but had been overlooked. The core was not available for examination by the writer.

The Barney Marble Company has spent a great deal of money in exploring the verd ridge, both by diamond drilling and by general excavations. Verd antique quarrying is a precarious business since the filling of the cracks in the serpentine by any other than carbonate minerals (calcite, magnesite, dolomite) results in unsound blocks which are valueless. Hence it happens that thousands of dollars may be expended in opening up a quarry, only to find that the verd is not fit for market. Diamond drilling will reveal the presence of the verd but not its soundness.

Farther north along the ridge the company has opened up the Tierney quarry (number 5), which is about three-quarters of a mile from the number 1 opening. This shows parallel lenses of verd lying in either side of a 25-foot core of green schist, with talc on their outer sides. There is the usual development of shear fiber and asbestos. The verd on the east side shows a peculiar mushroom structure at the top, as though, in swelling upward it had found less lateral resistance and so had expanded. Crosby's[1] *statenlith* theory, according to which the prominence of serpentine ridges and knolls is due to the increase in volume accompanying the serpentinization of basic, highly magnesian igneous rocks, is surely very suggestive here, as elsewhere in this region. The verd at this quarry is very unsound, the veining consisting, in places, of picrolite and crystolite one and a half inches wide. This of course spoils the rock. The quarry has been abandoned. Just north of the Tierney quarry, the ridge has been apparently down faulted, leaving a twenty-foot depression—a *cross cutter,* in local parlance.

The next exploratory opening is at the Ellis (number 3) quarry, half a mile farther north. Here there are three parallel green schist ridges, about half a mile apart, which extend northward for some miles. The Ellis quarry is on the most easterly. These quarries have not proved successful.

About a mile farther north, on the old Wiley (now the Scampini) farm, within a few rods of the Northfield line, a quarry (number 7) has been started on a verd lens, 350 feet long and 60 feet wide. This lens lies on the middle of the three ridges mentioned above. Here the verd has been found worthless for another reason. The serpentine is hard and well veined in places and would polish satisfactorily, were it not for the presence of much soft talcose material which of course ruins the rock.

Finally, at the Albin farm, on the road over Warren Mountain to Warren, one finds the most northwesterly outcrop thus far found in Roxbury. This is nearly pure serpentine, hardly any marble veining being seen. It may be said that some serpentine polishes to a very handsome dark green stone for which considerable use should be found; but at present, though the veined rock is in much demand, serpentine is valueless.

NORTHFIELD.

The serpentine in this town is found on the Moseley estate, about two miles north of the Barney Marble Company's number

[1] Journal of Geology, xxii, 6, p. 582.

7 quarry and some seven miles west of Northfield village. It is in line with the other serpentine outcrops and, with the enclosing country sericite, strikes about north, 20 degrees east.

The deposit takes the form of a long, low mound, 250 or 300 feet long by about 35 feet wide. The serpentine is much weathered and jointed and shows a considerable development of shear fiber (picrolite) and some dolomite veining, but it can hardly be called verd antique and probably has no commercial value. There has been some alteration of the serpentine to talc.

A brook has cut across one end of the lens and exposed a very good cross section, which shows the same sequence as at the Roxbury quarries—that is, from east to west: Country sericite schist, sericite schist with interlaminated green schist, green schist, serpentine, green schist, green-sericite schist, sericite.

The verd antique occurrences in Warren, Rochester, and Stockbridge have already been discussed (pages 238 and 240). Of these occurrences the only really promising one is in Warren, and lack of transportation facilities renders that practically unavailable for quarrying purposes. No verd deposits are known north of Northfield.

THE SERPENTINE AND VERD.

A study of thin sections of these rocks reveals a mass of leafy antigorite more or less altered to talc, with occasional patches of dolomite (proved to be dolomite by chemical tests on larger specimens). The amount of talc developed in the different specimens examined varies widely and affects very materially the value of the verd, as was seen at the Tierney quarry where the alteration to talc has rendered the rock worthless. In several places antigorite is included in the dolomite and this fact, together with similar inclusions in hard specimens, warrants the belief that the dolomite has filtered into the cracks and crevices of the serpentine, thus giving rise to the veining. Magnetite is found in all the slides, in places in small patches; at others, finely disseminated. One slide shows chromite in with the antigorite, dolomite, and talc. In another section a relatively large patch of magnetite includes antigorite, while elsewhere the carbonate mineral surrounds magnetite grains. This suggests that the magnetite is, in part at least, secondary and has resulted from the alteration of the rock which gave rise to the serpentine.

ANALYSIS OF THE SERPENTINE.

It would be manifestly impossible to secure an average sample of verd antique without crushing and sampling a large amount. Therefore a sample of the serpentine associated with the verd was selected and analyzed, showing the following composition:

SiO_2,	42.06%
Al_2O_3,	3.25%
Fe_2O_3,	1.60%
FeO,	3.40%
MnO,	.30%
MgO,	38.44%
H_2O+,	10.94%
H_2O-,	.29%
	100.28%

SERPENTINE NORTH OF NORTHFIELD.

The serpentine deposits north of Northfield, on the eastern chain of deposits are found in the towns of Eden, Lowell (and the mining hamlet of Chrysotile), Jay, Troy, and in Canada. No detailed work has been done on these deposits by the writer. In addition to the information given by Wigglesworth, elsewhere in this volume, there are available the monographs by C. H. Richardson (Asbestos in Vermont[1]), V. F. Marsters (Petrography of the amphibolite, serpentine, and associated asbestos deposits of Belvidere Mountain, Vt.[2]), and J. F. Kemp (Notes on the occurrence of asbestos in Lamoille and Orleans Counties, Vt.[3]).

Marsters states that there are a number of talc bearing lenses associated with the serpentine. "They contain nearly pure talc in the centers but grade out into the normal serpentine on either side, with loss of schistose structure." It will be recalled that in the Williams mine at Rochester some very pure chrysotile is found developed next to the blackwalls. We have, therefore, in Rochester, much talc and little chrysotile; in Lowell, much chrysotile and little talc; in Roxbury, verd antique with more nearly equal amounts of talc and chrysotile.

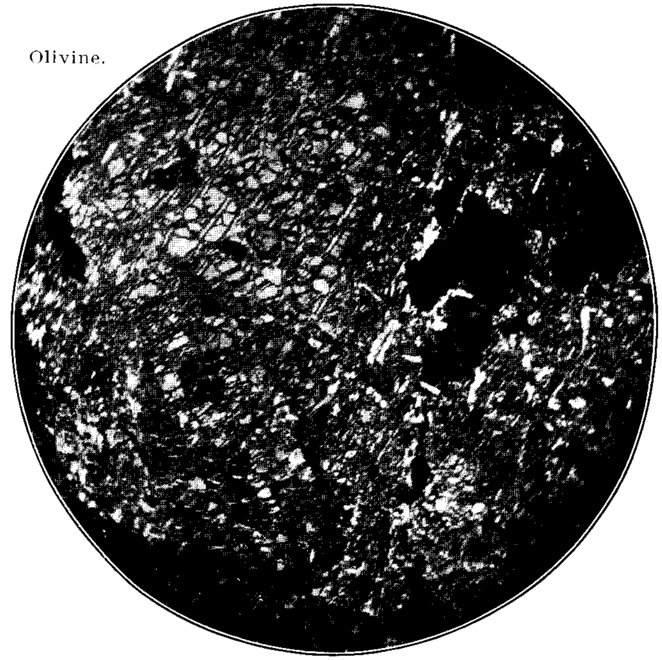
In the Province of Quebec, just over the International Boundary from North Troy, the Canadian Pacific Railroad has cut through a number of parallel serpentine ridges, which trend about east and west and so cut across the strike of the country schists. This serpentine is rather a bright green color and looks very fresh and compact. From its relation to the schists, it is evidently younger than the serpentine in Vermont.

THE GREEN SCHIST.

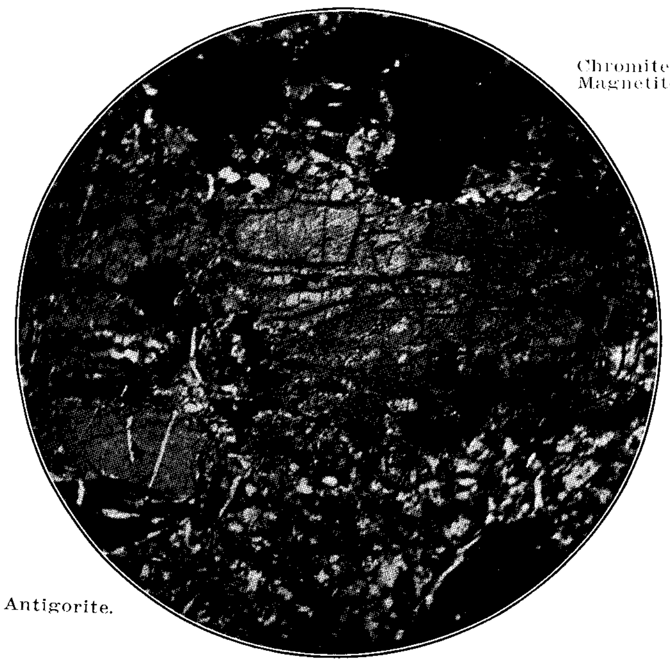
This rock, as has been seen, is closely associated with the serpentine, which is intruded into it, and gradually merges into

[1] Seventh Report of the Vermont State Geologist, 1909-10.
[2] Bulletin Geol. Society of America, vol. 16, pp. 449-466.
[3] Mineral Resources of the United States, 1900, pp. 862-866.

PLATE LXVII.



A. DOVER DUNITE.
X 30 (Polarized light).



B. LOWELL PYROXENITE.
X 30 (Polarized light)

the verd was selected and analyzed, showing the following composition:

SiO_2,	42.06%
Al_2O_3,	3.25%
Fe_2O_3,	1.60%
FeO,	3.40%
MnO,	.30%
MgO,	38.44%
H_2O+,	10.94%
H_2O-,	.29%
	100.28%

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A. DOVER DUNITE.
X 30 (Polarized light).

B. LOWELL PYROXENITE.
X 30 (Polarized light)

the country sericite. The schist is of a bright green color and, in the core of the ridge, between the verd lenses, it is homogeneous and rather coarsely laminated; while outside the verd lenses it becomes increasingly interlaminated with the sericite schist and finally disappears.

The formation suggests strongly a contact effect of the original intruded magma on the country rock. An investigation of this point is under way but has not yet sufficiently progressed to be reported upon at this time.

MICROSCOPIC STUDY OF THE SERPENTINES.

Mr. Edward Wigglesworth, whose article on the Vermont serpentines appears elsewhere in this volume, has kindly placed his collection of some sixty rock sections at the disposal of the writer. These have been studied in connection with the sections especially prepared for this article and the results will be given in considerable detail. The sections are representative of the serpentine and talc belt from Dover, Vt., on the south, to the Province of Quebec, on the north.

Dover.

In the Dover slides olivine forms the bulk of the sections. Crystal terminations are missing and in some sections the brilliant bire-fringent colors have all but disappeared, though the mesh structure is well developed and the alteration to antigorite is marked. There may be other ferromagnesian minerals present but the critical characteristics are lacking and therefore identification is impossible. There are some patches of magnetite and chromite, while iron sulphide (probably pyrrhotite) has been introduced into the cracks. The rock is evidently dunite.

The photomicrograph, Fig. A, (Plate LXVII) shows faintly the mesh structure of olivine phenochrysts, and the great alteration of olivine to antigorite that has gone on. There is some small amount of pyroxene present and some development of talc or brucite. The black, irregular patches are probably magnetite, though chromite may also be present. The magnetite is both primary and secondary, the latter resulting from the breaking up of the olivine.

Windham.

Of the five slides examined only one, that from North Windham, shows ferromagnesian minerals. This slide consists of large areas of olivine altering to antigorite and a few phenocrysts of augite (told by the rectangular cleavage and oblique extinction). Some of the olivine shows the orthorhombic outlines. The other slides reveal only leafy antigorite somewhat altered to talc, which crosses the sections in long ribands. In some of the sections calcite or dolomite is found scattered through the slides, a few basal sections showing excellent interference figures. Disseminated magnetite is found included in the dolomite as well as in larger areas. Regarding talc development, as Wigglesworth points out, this mineral is hardly ever found in the same slide with olivine but only when the alteration to antigorite is nearly or quite complete.

Proctorsville.

Four sections from the serpentines of this town were examined. Two of these show olivine much altered to long stringers of feathery antigorite which make up about half of the section. There may be a phenocryst or two of pyroxene. Fine grains of magnetite are found in the mesh structure of the olivine. Some of the larger black areas may be chromite as there seems to be a faint reddish tinge. There is some development of carbonate and both it and the antigorite contain much finely disseminated magnetite. In places the magnetite includes the olivine and is therefore secondary to it and probably derived from it. It is to be noted that magnetite occurs in practically every slide examined. In the other slides the ferromagnesian minerals are lacking and the sections contain about equal amounts of antigorite and dolomite. The dolomite includes flakes of antigorite. A few shreds of talc are noted.

Ludlow.

Sections from one location in this town show an advanced stage in the serpentinization of some ferromagnesian mineral. There is a small amount of chromite and much pyrrhotite. Another section shows a complete alteration to antigorite and a large development of carbonate. Magnetite is present.

Cavendish.

Cavendish sections show beautiful areas of olivine only moderately serpentinized, though the crystal outlines have been lost. There is much finely disseminated magnetite and a grain or two of chromite. In one of the sections pyroxene is probably present. The bent and twisted appearance of the serpentine fibers suggest crushing. A good deal of the magnetite dust shows a banded arrangement, as though it had formed in the cleavage cracks of the original mineral. No more olivine is seen till one comes to the Lowell sections.

Plymouth.

Here the slides show fine antigorite mixed with talc fibers. No primary minerals are seen but magnetite is present. Another section is made up entirely of fine grains of carbonate with shreds of talc lying between them.

Rochester.

The sections from this location show an entire absence of ferromagnesian minerals, being made up of felted antigorite, with magnetite both disseminated and in patches. A few stringers of talc are noted and small amounts of carbonate, some of which show twinning. Cushmans Hill, a half mile north of the Williams mine, is made up of antigorite with some development of carbonate and talc. The large dike traversing the hill is now composed of masses of chlorite containing many fine octahedrons of magnetite, and some carbonate.

Roxbury.

As already stated, the serpentine and verd antique sections here are entirely lacking in primary minerals, being made up of large, leafy antigorite, often with an equal area of dolomite. Magnetite occurs both in considerable patches and as fine dust scattered through the slides. The dolomite has at times many inclusions of antigorite and some magnetite; while at others, magnetite includes the dolomite. This suggests that some of the magnetite, at least, and the dolomite are of later formation than the antigorite. Hand specimens tell the same story, as already pointed out. Whether the dolomite was formed by the carbonation of calcium and magnesium derived from the original minerals is problematic (see page 251). A great deal of dolomite has come into the Roxbury serpentines from some source, at any rate, and it has come after the serpentinization of the original magma and even after the shearing which produced the chrysotile and picrolite.

Northfield.

A section from the Northfield serpentine discloses nothing new. The deposit could hardly be called verd antique.

Moretown.

The sections cut from the large serpentine mass forming the core of the lens, on whose borders the magnesia talc mine is opened show, when remote from the talc, large leafy antigorite, slightly altered to talc and associated with more or less magnetite. But as the talc deposit is approached the talc in the slides increases markedly and dolomite appears. In one section large patches of magnetite include antigorite, while in another much magnetite is included in the dolomite. Still another slide shows a gradual transition from antigorite, somewhat altered to talc, to talc containing residual antigorite. This section came from a "cobblestone" of serpentine embedded in the talc vein. Many such remnants were formerly found.

WATERBURY.

Waterbury sections show flaky antigorite, some carbonate with much antigorite included, more or less magnetite and not much talc. One section, near a prospect pit on a talc lens, shows, of course, an extensive alteration to talc.

DUXBURY.

The sections from here show interlaminated carbonate and talc, the latter beautifully developed and showing the brilliant polarization colors. Magnetite is found, as usual, and some chromite occurs. One section is remarkable for consisting of a confused mass of epidote, usually in stubby laths, antigorite, talc, carbonate, and many highly refracting grains of zircon or rutile. The patches of carbonate include many laths of epidote. Epidote is a common alteration product of ferromagnesian minerals and so suggests the igneous origin.

LOWELL.

In the Lowell sections there is noticed the reappearance of ferromagnesian minerals, not seen since the Cavendish slides.

A composite of the Lowell sections would show a ground mass of flaky antigorite containing phenochrysts of olivine, and pyroxene (probably augite) with the pyroxene predominating. Long stringers of a ferromagnesian mineral running through the sections indicate the alteration that has gone on. Associated with both minerals are considerable areas of chromite, some included in the ferromagnesian minerals. Fine chromite or magnetite dust is also scattered through the sections. Some of the sections show an infiltration of pyrrhotite, which is so common all over the talc belt. There is also some small amount of carbonate present and a little chlorite. The photomicrograph, Fig. B, (Plate LXVII) shows a large phenochryst of pyroxene in the center and a small one of olivine to the left. Flaky antigorite is seen surrounding these phenochrysts and invading them. The black areas are chromite and magnetite, which are both primary and secondary. Since the pyroxene mineral predominates over the olivine, the original rock which altered to serpentine is better called a pyroxenite than a peridotite. The chemical analyses of the neighboring Belvidere serpentine (p. 262, No. 6) do not bear out this conclusion but point rather to a dunite, as do the analyses as a whole.

CHRYSOTILE.

In this mining village of Lowell the alteration has gone on much more completely and the identification of component minerals in the sections is much more difficult. The slides show a felted ground mass of antigorite and a much altered ferromagnesian mineral. There are some remarkably large phenochrysts, probably pyroxene, whose cleavage cracks are filled with finely disseminated magnetite or chromite, giving them the appearance of intergrowths. In these sections the pyroxene has evidently survived the olivine as is to be expected.

TROY.

Sections here show the typical structure of serpentinized olivine phenochrysts, but alteration has gone so far that the birefringent colors of the olivine are lacking. Leafy antigorite surrounds the phenochrysts and either magnetite or chromite is disseminated and forms a network. Pyrrhotite has filtered into the cracks.

JAY.

The Jay sections show about the same condition as the Troy, but there is some development of carbonate.

PROVINCE OF QUEBEC.

Several sections from the serpentine ridges here show a ground mass of antigorite, somewhat altered to talc, with considerable patches of carbonate, some pyrrhotite, and the usual disseminated magnetite. There are a few old phenochrysts of a mineral showing parallel cleavage and parallel extinction. The phenochrysts are without boundaries and the birefringent color is first order yellow. The cleavage cracks are filled with antigorite. The optical properties suggest enstatite ($MgSiO_3$, usually with admixtures of $FeSiO_3$).

DISCUSSION.

A study of these sections suggests that the serpentine belt of this region may be divided into two phases; a very basic dunite phase, possibly the continuation of the western Massachusetts dunite, and perhaps a pyroxenitic phase, extending from Lowell northward into Quebec, identical with the Broughton phase described by Dresser.[1] The nature of the original rock in the central part cannot be determined by microscopic means; the evidence of chemical analysis will be given presently.

The writer is indebted to Professor Charles P. Berkey, of Columbia University, who has kindly examined two of the thin sections.

[1]Serpentine and the Associated Rocks of Southern Quebec, J. A. Dresser, Ottawa, Government Printing Bureau.

Magnetite is present in every section and in most cases, if not in all, it is secondary, since it includes antigorite and carbonate. It has evidently been derived from the olivine ($MgFeSiO_4$) or other ferromagnesian mineral, which was the parent of the serpentine. Chromite, when present, is a primary mineral.

Dolomite or calcite is always secondary to the original, parent mineral, since it includes the alteration product, antigorite. The carbonate both includes and is included in the magnetite, but it is more often secondary to the magnetic oxide. It has probably not been derived from the original mineral, since the analyses show too low a percentage of lime for a pyroxene. As has been seen, dolomite is intimately associated with the talc deposits and it will be discussed with them.

CHEMICAL COMPOSITION OF SERPENTINES.

The following analyses have been assembled for the purpose of comparing the composition of the serpentine in different parts of the State and in southern Quebec.

No. 1 is from Dover and is borrowed from Mr. Wigglesworth's article.
No. 2 is from Rochester, Cushman's Hill; analyzed in the writer's laboratory.
No. 3 is from Roxbury ridge; analyzed in the writer's laboratory.
No. 4 is from Northfield; analyzed in the writer's laboratory.
No. 5 is from Moretown, Magnesia mine; analyzed in the writer's laboratory.
No. 6 is from Belvidere; V. F. Marsters' analysis.[1]
No. 7 is from Thetford, Quebec; Franz Cirkel's analysis.
No. 8 is the theoretical composition of serpentine.[2]

	1	2	3	4	5	6	7	8
SiO_2	38.10	41.27	42.06	42.60	42.82	40.21	40.76	44.14
Al_2O_3	2.31	2.96	3.25	1.22	.57 }	5.73	....	....
Fe_2O_3	2.70	2.06	1.60	2.86	.60 }	...	3.05	....
FeO	3.48	7.17	3.40	4.37	5.43	....	.49	....
MnO	.11	.60	.30	.21	.00	....	....	....
TiO_2	....	.00	.00	.00	....	....	....	....
CaO	.00	.71	.00	1.05	1.07	.82	.35	....
MgO	42.04	33.40	38.44	36.62	37.61	40.98	42.32	42.97
K_2O	.15	....	....	....	....	....	....	....
Na_2O	.19	....	....	....	....	....	....	....
H_2O+	11.45	11.62	10.94	11.37	12.00	12.68	13.60	12.89
H_2O	....	.40	.29	.02	.14	....	....	....
	100.53	100.19	100.28	100.32	100.24	100.42	100.57	100.00

CO_2 not determined.

It is to be noted that the serpentine, throughout the length of the State, is very uniform in composition, the chief variants

[1] Bull. G. S. A., vol. 16, p. 444.
[2] $H_4 Mg_3 Si_2 O_9$, Kemp's Handbook of Rocks, p. 151.

being the magnesia, which averages 6 to 9 per cent lower in the middle than at the ends of the chain and the lime and FeO which tend to increase northward.

If these analyses be "recast" for magnetite, antigorite, and carbonate, using the percentage of water as a basis for computing the antigorite molecule, it will be found that the magnetite varies from 0.7 to 4 per cent, by weight, of the serpentine, antigorite constitutes about 87 per cent, and that the carbonate mineral is calcite, which constitutes from one to two per cent. The mineral form in which the other constituents are present cannot be determined.

The "range" of serpentine analysis is:

SiO_2	38	to	42.8
Al_2O_3	1	"	3
Fe_2O_3	1.6	"	2.8
FeO	3	"	7
MnO	.1	"	.6
CaO	0	"	.1
MgO	33	"	42
H_2O	10.9	"	12.6

The average analysis of the serpentines is:

SiO_2	41.37%
Al_2O_3	2.66
Fe_2O_3	1.96
FeO	4.77
MnO	.24
CaO	.56
MgO	37.62
H_2O	11.47
	100.65

If this average analysis be recalculated to an anhydrous silicate, we shall get as the approximate composition of the original magma which produced the serpentine the following:

		(1)	(2)
SiO_2	46.74%	36.7 % to 42.8	40 to 46 %
Al_2O_3	3.00	.30 " 2.33	2 " 7
Fe_2O_3	2.21	.18 " 1.36 }	10 " 15
FeO	5.39	5.01 " 29.96 }	
MnO	.27	.10 " 1.81	
CaO	.63	.12 " 1.43	5 " 9
MgO	42.50	28.48 " 51.64	20 " 30
	100.74		
Na_2O			0 " 1.5
K_2O			0 " 1

Except for the higher silica, the average analysis of the Vermont serpentine is nearer the range of olivine than of pyroxenite. Furthermore, the Dover sections are, practically, dunites and there is no conclusive evidence of pyroxenite till the Lowell sections are reached. Since all evidence of primary minerals is missing in the serpentine between Cavendish and Lowell, the conclusion as to the origin of the serpentine in this region must rest on the evidence of chemical analyses. This evidence points to dunite.

In summarizing, it may be said that the evidence at hand suggests that most of the Vermont serpentines have resulted from the

[1] Is the range of olivine analyses, from Dana.
[2] Is the range of peridotite analyses; Kemp.

alteration of a magma injected into the foliations of the sericite schists, and that this magma, somewhat more basic in the southern part of the range and more acidic at the northern, produced on crystallizing dunites at the one extreme and pyroxenites at the other.

THE TALC.

As has been seen, the talc deposits lie in the chain of talc and serpentine lenses extending from Windham, on the south, to Waterville, on the north. The talc lenses have not resisted erosion as successfully as have the serpentines and consequently do not appear as hillocks. The serpentine and talc deposits are very often closely associated, as at Rochester, Moretown, Johnson, and Roxbury.

A cross section of a typical talc lens from east to west shows:

(1) Blackwall, in most cases of unknown thickness, merging into country schist.

(2) Talc, varying in width from almost nothing to 20 or 30 feet, generally foliated where in contact with the blackwall but becoming denser farther away. The talc merges into (3) grit, which is the predominant member, reaching a maximum thickness of 190 feet.

(4) Another zone of talc.

(5) Another blackwall, merging into the sericite schist. In Moretown the grit core is replaced by serpentine, but small masses of grit occur in the talc. The talc and grit, in places, contain inclusions of blackwall material (called "cinder" by the miners). This is especially true at the Johnson mines, where they reach large dimensions.

Microscopically, the talc appears, in polarized light, as bright colored flakes on a dark background of a mineral having more of the properties of antigorite than of anything else. Figure A, (Plate LXVIII) gives the general appearance. Other sections reveal a more fibrous structure and in these the presence of antigorite is positive. In the Moretown sections, one of which is shown in Figure B, (Plate LXVIII) long fibers of antigorite are seen surrounded by talc. In the Williams Mine slides, a few sections show long prismatic faces and good basal sections of actinolite. These are sharply demarcated from the talc and appear to have crystallized simultaneously with it. On the contact between talc and blackwall, the sections show leaves of the blackwall mineral with talc filling the interstitial spaces. Pyrrhotite is present in nearly all the slides but magnetite is not seen. It will be recalled that magnetite is found in all serpentine sections. It may further be noted, as of general interest, that sections of French talc are almost identical with the Vermont slides. Near the grit, the sections show a few rhombic faces of dolomite.

A. WILLIAMS TALC.
X 45 (Polarized light).

Serpentine.

Talc.

B. MORETOWN SERPENTINE AND TALC.
X 45 (Polarized light).

THE GRIT.

Plate LXIX shows the relations of the talc, dolomite, and antigorite, in the grit. The talc is seen in fine flakes, the dolomite in large areas showing twinning striations, and the antigorite as dark patches.

In the previous report the writer thought the grit sections indicated that talc had resulted from the action of a silicate solution on dolomite. This theory, in light of all the observed facts, is untenable. The dolomite is secondary, as shown by grit sections and the field relations at the Roxbury verd deposits. In Moretown there is very little grit in the talc and this occurs in isolated, small masses.

The following analyses show the range in composition of the talc pretty much throughout the talc belt of the State. The analysis of the Williams grit is repeated, and there have also been added the analyses of the New York agalite and of talc from North Carolina, Austria, France, and Italy.

ANALYSES OF VERMONT TALC AND GRIT.

No. 1, Waterville talc, analysis made at M. I. T.
No. 2, Moretown talc, analysis made in writer's laboratory.
No. 3, Rochester talc, analysis made in writer's laboratory.
No. 4, Rochester grit, analysis made in writer's laboratory.

	1.	2.	3.	4.
SiO_2	61.06	60.21†	56.69	23.53
Al_2O_3	3.63	4.23	3.68	2.45
Fe_2O_3	....	.00	1.16	....
FeO	2.89	4.12†	3.77	5.26
Fe (for FeS)	....	....	.31	....
MnO	....	.28	.26	....
MgO	28.60	27.90	28.13	28.14
CaO	trace	.00	1.57	10.26
S	....	....	.20	....
H_2O+	3.92	4.90	4.60	1.40
H_2O-	....	.13	....	29.04[1]
	100.10	101.77	100.37	100.08

[1]Loss on ignition, excluding water.
†Probably high.

ANALYSES OF TALC FROM OTHER SOURCES.

No. 5, Agalite, St. Lawrence Co., N. Y.
No. 6, North Carolina, Hopkins.
No. 7, Austria.
No. 8, France, Mineral Industry, 1897, p. 634.
No. 9, Italy, Mineral Industry, 1897, p. 634.

	5.	6.	7.	8.	9.
SiO_2	62.10	60.26	59.59	50.91	51.23
Al_2O_3	....	.31	1.76	13.19	7.08
Fe_2O_3	....	....	....	....	....
FeO	1.30	.12	.79	2.58	1.89
MnO	....	....	....	....	....
MgO	32.40	34.52	32.92	24.86	33.32
CaO	....	1.28	.59	1.82	1.80
K_2O	2.15	.17	.56	....	.22
Na_2O		.24			
H_2O+	2.05	5.01	3.79[1]	6.64[1]	5.46[1]
	100.00	101.91	100.00	100.00	101.00

It is seen that the Vermont talc is very uniform in composition and that it is inferior in magnesia content to the New York, North Carolina, and most of the foreign mineral. The superior quality of the talc in the northern part of the State is due solely to color, which is largely controlled by the iron content. This iron seems to exist almost wholly as pyrrhotite, with now and then a little iron oxide. It has therefore been introduced and did not form a part of the original mineral. In analysis number 3, there is a small amount of ferric oxide, which presumably represents a small amount of magnetite, although the sections do not show it.

* * * * *

The foregoing represents the facts in the case of the serpentine, verd antique, talc, and grit. The problem presented is to account for the association of talc and grit and to reach a satisfactory theory for the origin of each. The following possibilities present themselves:

(1) The talc may have been derived from such basic magnesian silicates as olivine, tremolite, enstatite, diopside, amphibole, antigorite, or dolomite.

From olivine: $4(MgFe)_2SiO_4 + H_2O - 5(MgFe)O = H_2Mg_3Si_4O_{12}$, (talc).

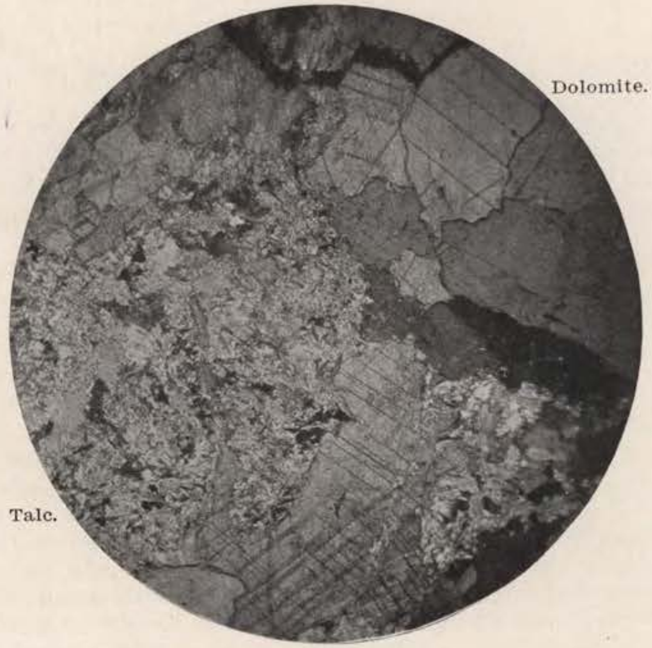
From enstatite: $4MgSiO_3 + CO_2 + H_2O = H_2Mg_3Si_4O_{12} + MgCO_3$.

From tremolite: $CaMg_3Si_4O_{12} + CO_2 + H_2O = H_2Mg_3Si_4O_{12} + CaCO_3$.

Of course the addition of water and carbon dioxide came from ground or magmatic waters holding carbon dioxide in solution, probably under considerable pressure.

[1]Including CO_2.

PLATE LXIX.



WILLIAMS GRIT.
X 45 (Polarized light).

(2) It may have been derived from some of the above minerals directly, or through what Julian[1] calls a colloid stage; thus,

$4MgFeSiO_4 + 8H_2O + O_2 + nH_2O = (H_4Mg_2Si_3O_{10}) + nH_2O.$ (colloid sepiolite)

then, $3H_4Mg_2Si_3O_{10} + nH_2O + \Delta = H_2Mg_3Si_4O_{12} + SiO_2 + 4H_2O + nH_2O.$ (heat)

Julian finds much to strengthen such a theory of origin as this.

(3) The talc may have been derived from antigorite, which had resulted from the alteration of some of the above primary minerals; thus, from olivine: $3Mg_3 Fe(SiO_4)_2 + 6H_2O + O = 3H_4Mg_3Si_2O_9 + Fe_3O_4.$
(antigorite)

Then, $2H_4Mg_3Si_2O_9 + 3CO_2 = H_2Mg_3Si_4O_{12} + 3MgCO_3 + 3H_2O.$

(4) The talc may have been derived from a magnesian limestone by the action of silicate solutions, perhaps through the intermediate formation of tremolite or enstatite. Smythe[2] has found this to be the case in the agalite deposits of northern New York.

The dolomite may have resulted from the alteration of primary minerals, simultaneously with the production of talc; thus,

$2CaMg_3 (SiO_3)_4 + 5CO_2 + H_2O = H_2Mg_3Si_4O_{12} + 3Mg CO_3 + 2CaCO_3 + 4SiO_2.$

Or it may have been derived from antigorite:

$2H_4Mg_3Si_2O_9 + 3CO_2 = H_2Mg_3Si_4O_{12} + 3MgCO_3 + 3H_2O$, if infiltering calcium carbonate could be dolomitized by the magnesium carbonate resulting from the reaction.

Or, the magnesium carbonate may have escaped and the dolomite have entered in solution and crystallized out.

In order to arrive at any safe conclusion, it is obviously necessary to take into account the whole mass of talc and grit. At the Williams Mine, on the fourth level, a section from west to east shows 6 feet of talc, 50 feet of grit, and 2 more feet of talc. If we consider a rectangular column (a parallelopiped), one foot square in section and 58 feet long, we shall have 8 cubic feet of talc and 50 cubic feet of grit. The specific gravity of talc is 2.8; of grit, 2.98. Then the weight of the talc will be 1400 pounds and that of the grit, 9,280 pounds. The analyses of the talc and grit here are:

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[1] A. Julian, Genesis of Antigorite and Talc, American Academy of Science, Vol. XXIV, 1914.
[2] Supra.

	Talc.	Grit.
SiO_2	53.68%	23.53%
Al_2O_3	2.02	2.45
FeO	*	5.26
MgO	28.98	28.14
CaO	1.54	10.26
H_2O	5.59	1.40
CO_2	1.21	29.04

From these percentages and the weights of talc and grit, we get, as the constituents of the whole mass:

SiO_2	2,991	pounds
Al_2O_3	257	"
FeO	488	"
MgO	3,047	"
CaO	975	"
H_2O	214	"
	7,972	pounds
CO_2	2,713	"
Total weight	10,685	pounds

The point may be raised that the constituents of the blackwall, which surely belong to the intrusion, should be added to the above figures. But it is not believed that they took any part in the alteration to talc, as will be shown later.

Now the water and carbon dioxide were taken on by the original mineral, in the process of metamorphism, and therefore, in order to get at the average composition of the original, primary mineral, these should be omitted and the remaining constituents increased *pro rata*. Doing this, we get as the average composition of the original mineral, or minerals:

SiO_2	38.55%
Al_2O_3	3.40
FeO	6.28
MgO	39.27
CaO	12.56
	100.06%

But in the whole range of olivine, pyroxenes, and amphiboles, there is not a single mineral with whose lime and magnesia contents the above figures can be reconciled; nor are such rocks as dunites, peridotites or pyroxenites admissible. It seems, therefore, that the dolomite must have come in from sources outside the original magma.

The normal dolomite contains:

CO_2	47.9%
CaO	30.4
MgO	21.7

*Iron and sulphur omitted since pyrrhotite is an introduced mineral.

It has already been shown (page 251) that the Roxbury dolomite has practically this composition. We may therefore proceed to subtract from the constituent weights of the whole mass of talc and grit enough lime and magnesia (based on the percent of carbon dioxide present) to form all the dolomite possible. If this be done, it will be found that there is not enough lime to form a normal dolomite—but this may be due to the sample analyzed not being an average one. If we take all the lime for the dolomite and a corresponding amount of magnesia, subtract these from the original weights (on page 268), eliminate the water, and also the iron (since it represents introduced pyrrhotite), and reduce the remaining quantities of silica, alumina, and magnesia to a percentage basis, we shall have, as the composition of what we may suppose to have been the original magma, the following:

SiO_2	58.95%
Al_2O_3	5.06
MgO	35.99
	100.00%

If this analysis be calculated to a mineral formula there will result $MgO\ \frac{Al_2O_3}{19}\ SiO_2$, which is enstatite, slightly contaminated with alumina. Moreover, the above analysis agrees very well with the enstatite analyses given by Dana.

Confessedly, the weak point in the argument is that there is a shortage of lime for the dolomite, though of course this mineral does not have a fixed composition. But until this point can be cleared up, the theory will be advanced that the talc and associated antigorite of the typical Vermont deposits (Windham, Rochester, Johnson, Cambridge, etc.) have been derived from enstatite and that the dolomite of the grit has been introduced. The theory of introduced dolomite is borne out by the evidence of thin sections from the Williams Mine, field relations at the Roxbury verd deposits and in the verd opening near the Williams Mine, as has already been stated.

The talc of the Roxbury deposits and of the Moretown deposit must be considered as having been derived from the antigorite of the serpentine intrusion, as has been shown. No other theory is permissible, for the evidence is clear and unmistakable. The origin of the serpentine has already been considered (see page 263.

Time has not permitted the writer to determine whether Julian's theory of intermediate "colloid" stages between the primary mineral and the talc can be supported by the data at hand, but it is hoped to continue this investigation in all its bearings.

As regards the conditions (heat, carbonation, pressure, etc.) under which the alteration of the original magma to talc and serpentine took place, this investigation has nothing to add to existing theories. Tremendous erosion must have gone on in the Green Mountains since their folding, at the close of the Ordovician period, and present land surfaces must have then been buried under many feet of sediments, hence under conditions of great heat and pressure.

THE BLACKWALLS AND CINDER.

It has been seen that the blackwall material borders all the talc and steatite deposits of the State[1] and at least the verd antique deposit at Roxbury. None of the strictly serpentine lenses has been opened up as far as the writer knows, but it is practically certain that these would also show the blackwall member. The blackwall seems to vary greatly in thickness (The Magnesia Talc Company has volunteered to bore through it, in order to get the thickness and to afford samples for investigation), the Williams Mine wall being at least 18 feet, and it merges gradually into the country schist, in places including it. Blackwall is a well laminated schist, dark green and lustrous in the southern part of the State, near the gneissic country rock; grayish black and dull, farther north. In the southern part of the State it included sizeable cubes of pyrite and crystals of hornblende, while in the central and northern part it has no megascopic inclusions. It is generally slickensided on the side next the talc, where movement has taken place, at times presenting a face of the smoothness of window glass.

The so-called cinder is generally nearly identical in appearance with the blackwall and occurs in small masses; but in East Johnson it is a light dove gray color and forms a great column in the talc and grit, near the mine shaft, 80 feet high, 3 or 4 feet square at the surface and increasing with depth.

Microscopically, both substances are seen to consist of a mineral which is more nearly allied to the chlorite group than to anything else, lacking however the pleochroism which characterizes chlorite. The mineral is sometimes granular, like the leptochlorites, while again it consists of rather large flakes, like the orthochlorites. It contains grains of titanite, at times (as do the sericitic country schists), shreds of talc, and more or less pyrite or pyrrhotite.

The following analyses, from the writer's laboratory, show the composition of blackwall and cinder, from Chester to Johnson. To these have been added the range of chlorite analyses given by Dana.

[1] It is probably identical with what the Georgia miners call "blue John," described by O. B. Hopkins in Asbestos, Talc and Soapstone Deposits of Georgia.

ANALYSES OF BLACKWALLS.[1]

No. 1 from Carlton Quarry, Chester, a dark green lustrous schist.
No. 2 from Williams Mine, Rochester, a grayish black, dull schist.
No. 3 from East Johnson Mines, a grayish black, dull schist.
No. 4 is "cinder" from East Johnson Mines, a dove colored schist.
No. 5 shows the "range" of analyses of the chlorite group.

	1.	2.	3.	4.	5.
SiO_2	27.07	27.10	28.67	29.34	29 % to 33%
Al_2O_3	21.98	23.25	24.06	21.18	13 to 21
Fe_2O_3	3.40	2.25	1.01	2.33	0.7 to 5.7
FeO	10.74	10.48	8.63	8.93	7.8 to 17.4
MnO	.31	.47	.51	.67	.16 to 2.3
CaO	.00	.65	.23	.00	.6 to 1.3
MgO	23.37	24.00	24.11	24.58	17 to 35
TiO_2					few hundredths
K_2O					few hundredths
Na_2O					few hundredths
S	.20	.04	.17	.05	
H_2O+	10.71	11.81	11.96	12.16	12 to 14
H_2O-	.39	.35	.25	.03	
	98.17	100.40	99.60	99.27	

The "range" of blackwall analyses and the average blackwall analysis are, respectively:

	Range	Average
SiO_2	27 to 29 %	and 28.0 %
Al_2O_3	21 to 24	and 22.6
Fe_2O_3	1 to 3	and 2.5
FeO	8 to 10	and 9.6
MnO	.3 to .6	and .49
CaO	.0 to .6	and .22
MgO	23 to 24	and 24.01
H_2O	10.7 to 12	and 11.66
		99.08%

Comparing the analyses of blackwall with those of our serpentine (pages 262 and 271) and chlorite, we see that the blackwall is 11 to 13 percent lower in silica than serpentine; 2 percent lower to 4 percent higher than chlorite; 20 to 21 percent higher in alumina than serpentine; 8 to 3 percent higher than chlorite; 10 to 18 percent lower in magnesia than serpentine; within the range of chlorite. The other constituents fall within the ranges of serpentine and chlorite.

If we calculate a formula to fit the average analysis of the blackwall, we get nearly, $H_{20}(Mg,Ca,Mn,Fe'')_{11}$ $(Al,Fé'')_7$ Si_7 O_{45}, which approximates the formula for delessite, $H_{10}(MgFe'')_4$ $(AlFe''')_4$ Si_4O_{23}. The optical properties and mode of occurrence of the blackwall and of this mineral are, however, markedly different.

The blackwall and cinder thus appear to consist of an undescribed mineral or minerals, which will be further investigated.

[1] The writer is indebted to his advanced students for several of the serpentine and blackwall analyses.

It seems to the writer that this blackwall material must represent a differentiate from the original magma and that its schistosity must have been induced by movement near the walls, where slickensiding is abundant. In light of physico-chemical principles, the theory is advanced that the blackwall material was originally a "solid solution which resulted from the cooling of the original, injected magma, this cooling of course being more rapid near the walls than farther away from them; and that movement, probably resulting from the change of volume of the original blackwall material, which would be associated with its hydration and alteration to its present composition, has produced the schistosity. If this be true, the composition of the original, injected magma must have been somewhere between that of enstatite and the blackwall material. The lack of knowledge regarding the thickness of this blackwall prevents a calculation of the average chemical composition of the whole intrusion.

It is believed, therefore, that the typical talc deposits of Vermont have resulted from the injection into pre-existing cavities or zones of weakness (chonolithic injections), caused by mountain folding or subsequent faulting, of a magma intermediate in composition between enstatite and the blackwall material; that magmatic differentiation has separated this material into two phases; and that metamorphic processes and resulting changes in volume have produced the talc, the grit, and the blackwall.

It is extremely probable that the serpentine lenses have had a similar history, as regards origin, though, as Wigglesworth points out, there are grounds for believing that these lenses are later than the talc lenses (those just across the International Boundary surely are). In Moretown and Roxbury talc has been produced in large amounts from the serpentine. The development of verd antique seems to have been entirely fortuitous, dependent upon the presence of carbonate solutions.

SUMMARY.

This report has shown that there are two parallel chains of mixed talc and serpentine lenses traversing the State along two of the north-and-south-running valleys of the Green Mountain Range, which is a part of the Appalachian Mountain System of metamorphic rocks. Not less than 33 occurrences of talc and at least 30 occurrences of serpentine have been noted.

From the evidence afforded by the great Williams deposit at Rochester, it seems probable that all the lenses were formed by the injection into the preexisting cavities ("chonolithic" injections) or else into zones of weakness, due to the mountain folding, of a magma which was the source of the serpentine, on the one hand, and of the talc, on the other. The serpentine is less altered than the talc and its "contact" effect on the country rocks is different; hence it is believed that it represents a later, and different, intrusion than does the talc.

In the southern part of the State, the serpentine is shown, by direct evidence, to have been derived from dunite. In the central part of the mineralized zone, where thin sections show no primary minerals, chemical analyses point to the same conclusion. In the northern part, at Lowell, a pyroxenite phase appears and is perhaps the southern extension of the Broughton phase of the Quebec serpentines. In Stockbridge, Rochester, Warren, Roxbury (especially), and to a small extent in Northfield and Moretown, dolomite, filtering into the pores and cracks of the serpentine, has produced the variety of serpentine known as verd antique; while in Roxbury, and especially Moretown, the serpentine has been extensively altered to talc. Other metamorphic minerals, actinolite, chrysotile, picrolite, etc., have also been developed.

It has been seen that the best talc mines are located on the western chain of deposits and that a typical lens consists of a great central "core" of grit (mixed talc and dolomite), with a talc member on either side, bounded in turn, by a highly magnesian schist called blackwall, which merges gradually into the sericite schist which forms the country rock of the region. The evidence is believed to support the theory that the origin of the talc and blackwall materials was a "chonolithic" injection of a magma which was differentiated, on cooling, into two substances, the one giving rise to talc; the other, being concentrated near the margins of the injection and subjected to movement, to the blackwall. It is further believed that infiltering dolomite has produced the grit member in the talc deposits, just as it has produced the verd antique, in the serpentine lenses. The verd lens, adjoining the Williams talc mine, shows the dolomite in solution to have been close at hand.

By recalculation of the talc analyses, on the theory that the dolomite of the grit and the disseminated pyrrhotite have been introduced, it has been found that the original mineral, which on being metamorphosed produced the talc, was enstatite. No direct microscopic evidence of this or other original mineral, however, has been found.

Chemical analyses and microscopic study show that the blackwall probably varies in mineralogical composition (as the theory of its being a "solid solution" demands that it should) and that it consists, perhaps, of new mineral species. This point will be further investigated.

OCCURRENCE AND PRODUCTION.

The consumption of talc in this country has shown a steady increase, due to greater imports and to greater domestic production.

The imports, ground or manufactured, in short tons have been as follows:[1]

	1913 Quantity	1913 Average price	1914 Quantity	1914 Average price	1915 Quantity	1915 Average price
Austria Hungary	391	$23.37	587	$18.43	138	$21.88
Belgium	8	26.13	...	....	...	....
Canada	3348	9.89	5006	11.20	4797	12.08
England	34	16.38	62	13.76	....	....
France	5466	5.17	4398	5.24	3734	5.16
Germany	15	123.07	53	112.55	8	236.00
Italy	4510	14.45	5535	14.41	7268	14.36
Netherlands	2	26.00	....	....	....	....
Japan	....	....	3	15.66	....	....
	13,774	$10.04	15,644	$11.29	15,945	$11.70

These figures may be compared with the total imports of former years:

	Short tons	Average price
1908	7429	$13.07
1909	4417	12.74
1910	8378	12.71
1911	7113	12.38
1912	10,989	11.19

This shows that imports have more than doubled in eight years. It is interesting to note the effect of the war on the talc producing countries, Italy and Canada being the chief gainers. The quality of the German talc is very high, judging from the fabulous price paid for the eight tons which arrived in 1915.

The sources of the French, Italian and Austrian talc were given in the first talc report.

Regarding Canadian talc, the Mining Journal for Jan. 16, 1915, says: "Near Madoc, in the County of Hastings, Ontario, an extensive body of white, massive talc has been mined for some years, part of the product being shipped in lump form to the United States and the balance milled locally. The mineral is of high quality, low in lime and free silica, and commercially is considered quite equal to the fine French varieties. It has been formed by the metamorphism of a magnesia limestone, due to the proximity of an intrusion of granite. A slightly discernible foliation is noticeable in the mineral and some tremolite may be seen scattered through the body, suggesting an intermediate tremolitic stage during alteration from dolomite. North of this occurrence some ten miles another body of similar material is being mined and milled on the ground, turning out an excellent product. Through the surrounding district other occurrences of white and

[1] Mineral Resources of the United States.
Figures furnished by the Department of Commerce, May 6, 1916. The values given "are the actual market values and wholesale prices of the merchandise at the time of exportation to the United States in the principal markets of the country whence the same has been imported."

colored talcs may be noticed, many of which are capable of supplying material suitable for a variety of uses."

The following is an analysis of the Hastings County talc:

SiO_2	60.45%
MgO	29.84
Al_2O_3	0.27
FeO, Fe_2O_3	2.82
Nio	0.50
CaO	0.50
H_2O	6.74
	101.12%

"Talc, serpentine, and soapstone are plentifully distributed through the eastern part of Quebec, and the talc deposits in particular have been highly spoken of, though up to the present they have been entirely ignored."[1] It is to be noticed that Canadian talc, selling in 1915 at $12 a ton, commands nearly 50 percent higher prices than the average American product (8.42).

TALC PRODUCTION IN THE UNITED STATES.[2]

	1913 Quantity	1913 Value	1914 Quantity	1914 Value	1915 Quantity	1915 Value
New York	81,705	$788,500	86,075	$821,286	88,214	$864,843
Vermont	44,447	302,375	50,123	358,465	61,997	406,652
Pa. & N. J.	11,308	80,780	7,732	54,549	7,989	56,466
North Carolina	4,576	48,317	1,198	28,413	1,454	21,501
Ga. & Mass.	3,309	35,416	3,627	57,927	2,934	25,971
Virginia	2,974	18,632	1,786	11,448	3,036	18,579
California	952	6,000	547	8,786	712	7,185
	149,271	$1,280,020	151,088	$1,340,874	166,336	$1,401,197

From these figures it is seen that Vermont has shown the largest increase, both in tons produced and in total value. Vermont's production for 1915 shows an increase over 1914 of 11,874 tons; or 23.6 percent; while New York showed a gain for the same time of 2,139 tons, or 2.4 percent. Still, of course, New York is by far the greatest producer, contributing 54% of the whole, to Vermont's 27%, in 1913; 50% to 33% in 1914; and 53% to 37% in 1915. Vermont is, however, fast "catching up."

The New York source of supply is St. Lawrence County and the talc here is derived from tremolite, as shown by C. H. Smythe.[3] The product is a fine white, fibrous material, called agalite, which brings $2 to $3 more a ton than the massive talc of other states and is largely used as a filler for superior grades of paper.

Pennsylvania and New Jersey have long been steady producers of talc and soapstone. The entire production comes from

[1] The Mineral Industry, 1914.
[2] Mineral Resources of the United States, 1914-15.
[3] School of Mines Quarterly, July, 1896.

quarries on either side of the Delaware River, a mile or so northeast and southwest of the city of Easton. The ground material sells as "mineral pulp" and is used largely in the manufacture of paper, paint, and rubber.[1]

The North Carolina talc is very compact and is used today principally for sawing into pencils, a ton of pencils selling for $500. It is also used for gas and acetylene tips and high grade insulators.[2]

The reason for the high price of Georgia and Massachusetts talc in 1914 (given as $15.97) is unknown to the writer. The price in the following year was $8.85, so that the former figure is probably a mistake.

Virginia is noted chiefly as a producer of soapstone, in which industry she exceeds all other states. In Fairfax County she also possesses talc deposits (the "Bull Run Talc") which is used as a substitute for graphite.[2]

"The recent discovery of talc of excellent quality and in commercial quantities in San Bernardino and Inyo Counties, California, promises much for the industry in the western part of the United States, and the demand for talc in the West may be supplied from this locality, thus saving the expense of the transcontinental haul. The deposits occur along the border of a diorite intrusion into banded, impure limestones. The effect of the diorite intrusions on the limestones seems to have been to alter them to masses of tremolite, which were subsequently altered by dynamical or other processes to talc. The quality of the talc is excellent, being exceptionally white, soft, and slippery, and under the microscope it shows a finely fibrous character, as does most of the talc elsewhere that results from the alteration of the mineral tremolite. The deposits have been opened up and to a certain extent developed in three localities: Zabriskie and Tecopa, in Inyo County, and at Riggs, San Bernardino County."[1]

TALC PRODUCTION IN VERMONT.

The production of talc here is confined to the same five companies which alone were active in 1914 (the date of the first talc report) namely: the Eastern Talc Company at Rochester, East Granville, and Cambridge, the Magnesia Talc Company at Moretown, the American Mineral Company at Johnson, the Vermont Talc Company at Windham, and the American Soapstone Finish Company at Chester Depot.

The following statistics are taken from "Mineral Resources of the United States," save those for 1915, which have been compiled from the returns made to the writer by the above mentioned companies:

[1] Frederick B. Peck, in The Mineral Industry, 1914.
[2] Asbestos, Talc, and Soapstone Deposits of Georgia, O. B. Hopkins.

PLATE LXX.

VERMONT TALC COMPANY'S MILL AT CHESTER DEPOT.

1.	Short tons.	Value.	(Average per ton).
1905	8,978	$ 65,525	$7.29
1906	10,413	101,057	9.70
1907	16,200	82,500	5.09
1908	10,755	99,741	9.27
1909	23,626	120,329	5.09
1910	25,975	136,674	5.26
1911	29,488	200,015	6.78
1912	42,413	275,679	6.49
1913	45,547	327,375	7.18
1914	50,123	358,465	7.15
1915	61,977	443,494	7.15

These figures show the great development of the talc industry in the State since 1905 and the tremendous increase in wealth resulting therefrom. With the locating of many new deposits and the increase in equipment by most of the companies, it may reasonably be expected that an even greater production will be attained in the future. Among the companies there is much sharp competition which results in a smaller margin of profit than is warranted by the capital invested.

USES OF TALC.

Mineral Resources for 1915 classifies manufactured talc and soapstone as follows:

Classification of talc and soapstone sold in the United States, 1914 and 1915.

Condition in which sold.	1914 Quantity (short tons).	1914 Value.	1914 Average price per ton.	1915 Quantity (short tons).	1915 Value.	1915 Average price per ton.
Rough	3,080	$ 17,941	$ 5.83	8,535	$ 59,392	$ 6.96
Sawed into slabs.	2,913	80,238	27.54	2,090	47,070	22.52
Manufactured articles[1]	17,824	498,802	27.98	16,088	444,679	27.64
Ground	148,479	1,268,106	8.54	160,178	1,340,441	8.37
	172,296	$1,865,087	$10.82	186,891	$1,891,582	$10.12

It will be noted that about 85 percent of the whole product is ground and of this probably the greatest part is used for paper filling. The highest grades are used for toilet purposes, for filling enamel paints, and sizing cotton cloths. Poorer grades are used for filling roofing paper, rubber goods, leather dressing, in

[1] Includes bath and laundry tubs; fire brick for stoves, heaters, etc.; hearthstones, mantels, sinks, griddles, slate pencils, gas tips, burner blanks, crayons, and numerous other articles for everyday use.

the poorer grades of soap, composition flooring, plaster board, soapstone finish as a substitute for plaster, foundry facings (use fast increasing), as a lubricant, in the ceramic arts, etc. As a foundry facing it has proved a very satisfactory substitute for graphite, whose increasing price is rendering it prohibitive for this purpose. As a lubricant, the Mineral Industry states: "In an extremely finely divided or 'deflocculated' state, talc remains suspended in water or oil. Deflocculated graphite is used in the manufacture of heavy lubricants, and deflocculated talc appears to be equally serviceable. The process of deflocculation, as devised by the German chemist, F. Thalberg, is accomplished by one of the two following methods: Clean, powdered talc is heated with ammonium carbonate and the heated mass plunged into cold water. A fairly stable suspension is obtained. If a dry stream of ammonia is passed over powdered talc the result is even better and an excellent, difficultly filterable suspension in water or oil is produced. The drying of the ammonia-heated talc must be done in vacuum, since heat causes agglomeration of the particles. After suspension of the treated talc in a liquid medium, heating has no effect. The equilibrium is probably

$$(4SiO_2\ 3MgO)H_2O + NH_3 = (4SiO_2\ 3MgO)NH_3 + H_2O."$$

Now as a possible material for deflocculated talc, the writer suggests the "blackwall," of which thousands of tons are lying on the dumps of the talc companies. Analyses of this material, given on page 271, show it to contain from 23 to 24 percent of magnesia, as compared with the 28 percent contained in the talc. It is probable that the ground blackwall has a good "slip," while the color would of course be no objection. The talc companies would find it well worth while to investigate this matter.

PRODUCTION OF VERD ANTIQUE.

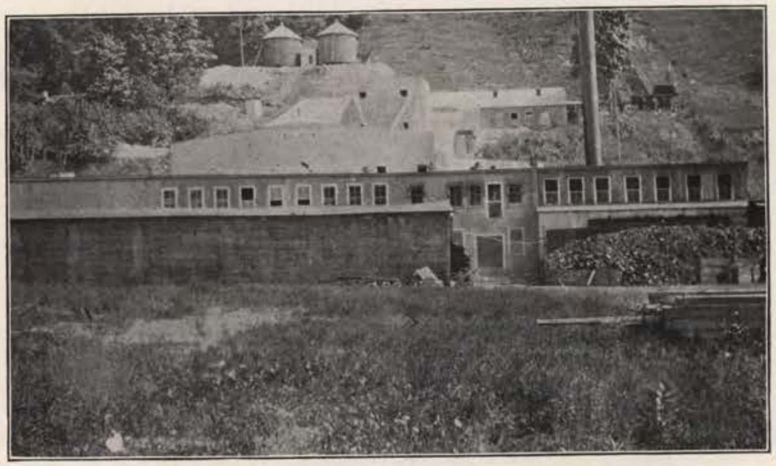
No statistics of production of verd for the states other than Vermont are available, as this stone is included under the head of marble. In this State, the Vermont Marble Company is producing about 60,000 cubic feet a year and the selling price has been lately raised from $3.25 to $3.75 per cubic foot.

ECONOMIC NOTES.

Windham.

Since the removal of its mill, in 1912, from the mine to the present site by the railroad, at Chester, the Vermont Talc Company has largely increased its tonnage of talc and also has effected important economies in milling. A second Raymond roller mill is being installed and other steps taken further to increase production. The illustration (Plate LXX) shows the mill. It has al-

PLATE LXXI.



EASTERN TALC COMPANY'S MILL AT ROCHESTER.

ready been noted that the company is considering the opening up of its deposit by an adit into the base of the hill wherein the talc lenses are located. Such an adit would materially reduce mining charges. The officers of the company are: President, Nathan P. Avery, of Holyoke, Mass.; Treasurer, J. N. Hubbard, of Holyoke; Mill Superintendent, B. J. Monier, of Chester Depot.

CHESTER.

The Carlton quarry, about three miles from Chester Depot, is still being operated by the American Soapstone Finish Company, of which Mr. C. P. Dodge, of Amherst, N. H., is President and Mr. E. E. Holt, Superintendent. The company continues to manufacture a "soapstone finish," which is said to be an excellent substitute for plaster, material for plaster board, roofing paper, dusting powder for automobiles, etc., etc.

ROCHESTER.

The Eastern Talc Company's mill number 2 burned down in the spring of 1915. Since then the company has completed a new structure, as an addition to its number 3 mill, thus securing a single large mill with all the advantages and economies resulting from compactness. This new number 3 mill is situated in the Talcville district of Rochester, about 250 feet below the terminus of the narrow gauge railroad which brings the talc material from the various mines, four miles away. The illustration (Plate LXXI) shows the mill and railroad terminus. The mill is now equipped with the latest drying and crushing machinery, as well as with a sprinkling system and other improvements, and is capable of producing a very large tonnage of the various talc products, at a low cost. A new office building is now being planned to accommodate the increased engineering force of the company.

The narrow gauge railroad, completed in 1913, has been able to do its work the year round, greatly expediting production and decreasing haulage costs. The road formerly ended at the top of an old river terrace above the mill, from which gravity cars carried the talc down to the bins. This procedure involved considerable labor costs which are now in process of being eliminated by bringing the road down to the level of the storage bins, by means of a series of "switch backs." There seems to be nothing new to report at the East Granville plant.

The officers of the company are: President, Freeland Jewett, of Boston; Vice-President, T. Ledyard Smith, of Boston; General Superintendent, C. B. Hollis, of Randolph; Mine Captain, Joseph Winot; Engineers, B. F. Jacobs, E. G. Brooks, H. A. Linke.

Johnson.

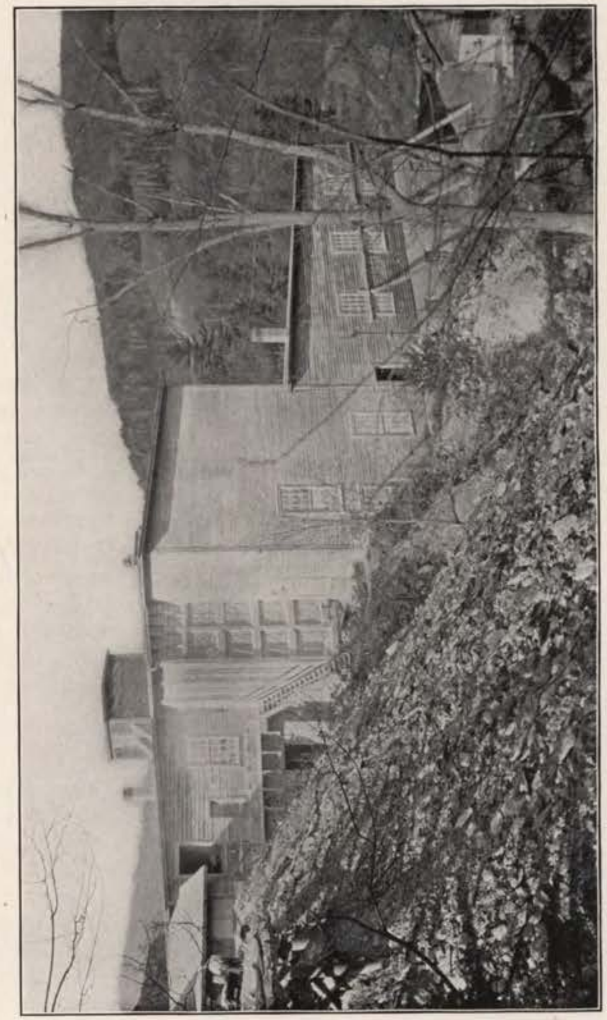
There has been a reorganization of the American Mineral Company since the last report. The new officers are: President, H. J. Potter, of Boston; Treasurer and Manager, H. N. Gordon, of Johnson; Mining Engineer, W. R. Reilly. The company is at work on its East Johnson mines and hauling the material to the old mill by the railroad. An aerial tram to connect mine and mill is being considered. The capacity of the mill has been doubled by the addition of the latest "cage" type of Raymond pulverizer. A Ruggles-Coles dryer, a type fast coming into favor in the talc business, will probably soon be added. The quality of the talc is probably the best in the State and the company is rapidly increasing its business.

Moretown.

Since the previous report the Magnesia Talc Company has much enlarged the size and capacity of its mill, adding new grinding units, a Ruggles-Coles dryer, new air compressors, bagging machines, etc., with the result that it is now able to produce a much larger tonnage of talc at very low cost. An aerial tram, or else a bridge across the river, is now under consideration, in order to expedite shipping facilities. The illustration (Plate LXXII) shows the mill and its connection with the tramway from the adit of the mine. The adits are lighted by electricity and many improvements in mining methods have been effected, which have greatly expedited and cheapened production.

The officers are: President, Elias Lyman, of Burlington; Vice-President, G. H. Holden; Secretary and Treasurer, J. S. Patrick; Superintendent, J. T. Smith; Mining Engineer, W. L. Scanlan.

PLATE LXXII.



MAGNESIA TALC COMPANY'S MILL AT MORETOWN.

THE SERPENTINES OF VERMONT.[1]

EDWARD WIGGLESWORTH,
HARVARD UNIVERSITY.

INTRODUCTION.

Although it has long been known that there is a considerable development of serpentine in Vermont, no special study has ever been made of its nature and distribution as a whole, since the report on the "Geology of Vermont" by Hitchcock (1), published in 1861. There are, however, reports on the asbestos-bearing serpentine in the northern part of the State by C. H. Richardson (2, 3) and V. F. Marsters (4). In the summer of 1912 the writer visited some of the occurrences of this rock in the State, and collected material for a petrographic examination at a later date. The results are briefly given in the following pages.

DISTRIBUTION.

The occurrences in Vermont form one part of the fairly continuous band of serpentine which exists in the eastern part of the United States and Canada. This band extends with many interruptions from Alabama, parallel to the Appalachian structure, as far as the Gaspé Peninsula, and even into Newfoundland. The rock in Vermont is therefore only a small section of a very extensive band.

There are over twenty localities from which serpentine has been reported. These localities align themselves in a direction approximately north and south, and thus correspond to the general trend of structure in the State. The line thus formed lies on the east side of the axis of the Green Mountains, and therefore in the eastern half of the State. The individual occurrences

[1] By request of the State Geologist, Mr. Wigglesworth has furnished a copy of this paper for publication in the present Report.

Originally printed in Proceedings of the Boston Society of Natural History, Vol. 35, pp. 95-107, 1915, it has been revised by the author and a few changes introduced.

Acknowledgement is made to the Society for permission to republish the article and for the use of the accompanying figure and plate.

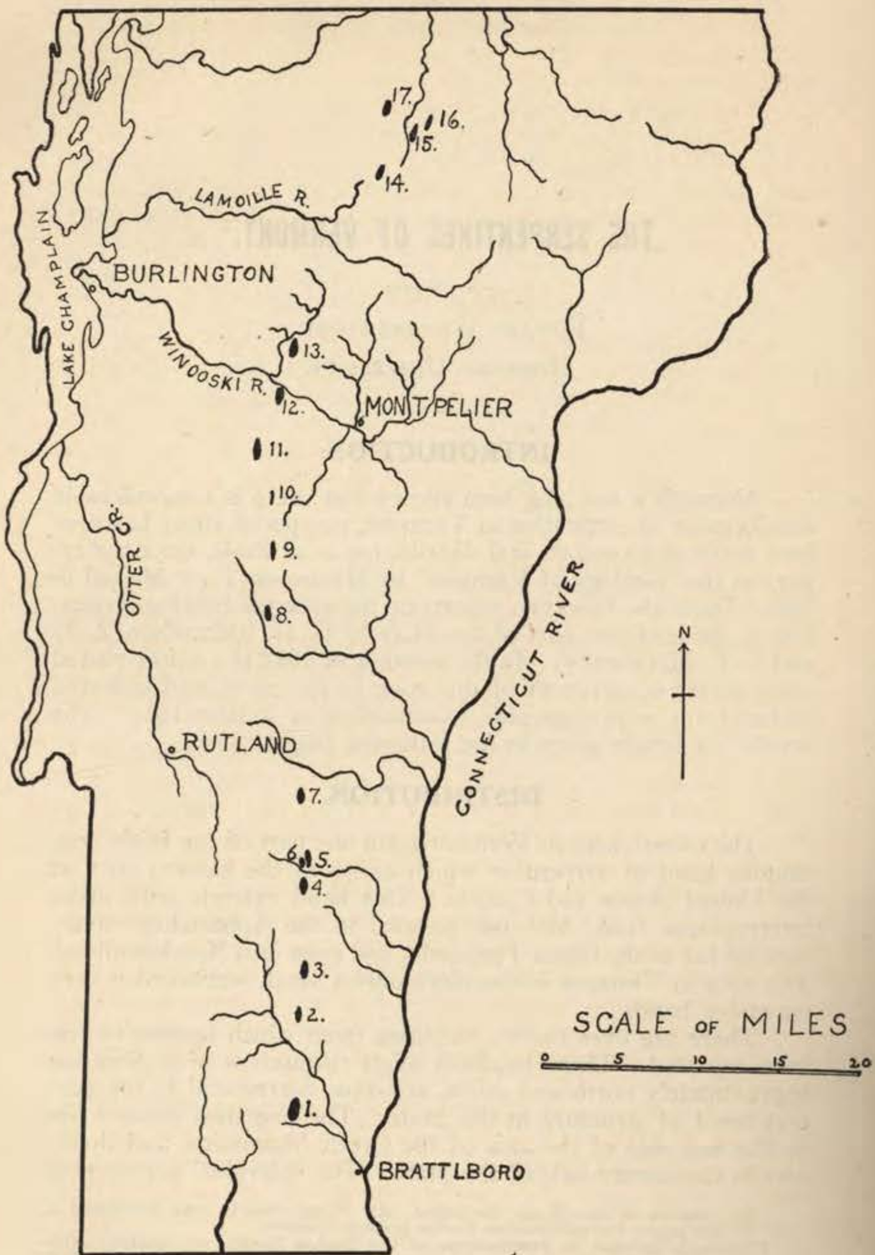


FIGURE 9.—Distribution of Serpentine areas in Vermont.

vary greatly in size, some being two or three miles long while others are not more than two hundred feet. The largest are found in the northern part of the State where the band seems to split up or widen out, so that in some places two nearly parallel ridges are seen. This more extensive development of serpentine in the northern part of the State is interesting as it is not very much farther north, in Quebec, that this same serpentine band become of great importance and contains the largest deposits of asbestos thus far discovered.

GEOLOGY.

One of the chief rocks of eastern Vermont, and the rock in which the serpentine areas are found, is a mica schist. This lies for the most part very highly inclined, and strikes nearly north and south, except in the north where it turns in a somewhat more easterly direction. The attitude and composition of these schists render them particularly susceptible to weathering, and therefore fresh rock is rarely found. For this reason, the actual character of the schists is hard to determine. Minor variations are seen, however, in different places; sericite can often be determined, while garnet, chlorite, and other minerals are found locally. The age of these schists has not been definitely determined. In Quebec, Dresser(5) states that the serpentines are intrusive into sediments of Middle Ordovician age, but Richardson(2) maintains that in northern Vermont the Ordovician terranes are not cut by the serpentines.

The shape of all the smaller serpentine outcrops is lenticular. This is undoubtedly true of all the localities except those in the north and the large one in the towns of Dover and Newfane. The lenses have their long axes parallel to the foliation of the schist, and are usually about four times as long as they are broad. The serpentine has the appearance of being concordant with the schists, but the fact that the latter weather more rapidly than the serpentine makes this relation difficult to determine. In most cases the serpentine forms a small hill, while surrounding schist is covered by swampy ground. In one or two instances the foliation of the schist follows the outline of the serpentine body, which suggests that the schist has been forced aside to make room for the serpentine.

The larger areas of the serpentine are likewise elongated in the direction of the strike of the schist, and show other evidences of being concordant injections. They have, however, in the north been described as batholiths, and are there certainly of batholithic proportions. In the asbestos region of Quebec there are thought to be two kinds of serpentine: one in the form of batholiths, the other in sills or sheets. It is possible that the large masses in northern Vermont may correspond to the batholiths.

Soapstone is frequently found associated with the serpentine, occasionally in the same outcrop, but more often as a separate occurrence near by. Such areas of soapstone or steatite are even more common than those of serpentine, and in some instances, when relatively free from impurities, they are mined for talc. In form, and in their relation to the surrounding rocks, these are very similar to the serpentine. In the southern part of the State the serpentine is often associated with amphibolite, a probable continuation of the amphibolite of western Massachusetts. Farther north, chlorite schist takes the place of amphibolite.

OCCURRENCES.

A description of each occurrence of serpentine would involve much repetition, as they are all very similar and vary only in size and details. They are therefore merely listed, beginning at the southern end, with a statement of the intervening distance, their location, and where possible their size. The most typical area, that of Waterbury, is described in detail as an example of what is to be found in the others.

1. *Dover.* On the town line between Dover and Newfane, the most southern area in the State. About two miles long.
2. *South Windham.* About twelve miles north-northeast of the last area, and about two miles west of the southeast corner of the town. Length, one-fourth of a mile.
3. *North Windham.* About four and a half miles north of the South Windham area, and one mile north of the village. Length indefinite but small.
4. *Cavendish.* About thirteen miles north of North Windham, on the western boundary of the town, just south of the Black River. Length indefinite but probably large.
5. *Cavendish.* About one-fourth of a mile northeast of the last, on the north side of the river. Length indefinite, about one-half mile wide.
6. *Ludlow.* Directly west of the last and on the Ludlow-Cavendish boundary. Length, about one-half mile.
7. *Plymouth.* Eight miles north of the Ludlow area at Plymouth Five Corners. Only seen on a section on the brook.
8. *Rochester.* Twenty-five miles north of Plymouth Five Corners. About one-fourth of a mile north of Eastern Talc Co.'s mine. Length, 200 yards.
9. *Roxbury.* Thirteen and one-half miles north of Rochester, just south of the village of West Roxbury on the Central Vermont R. R. Length indefinite but not large.
10. *Northfield.* Five and a half miles north of the Roxbury area, near west boundary of the town. Length, 125 yards, width 5 yards.

WATERBURY. NORTH END OF SERPENTINE AREA. TYPICAL SURFACE OF SERPENTINE OUTCROP.

WATERBURY. GENERAL VIEW OF THE SERPENTINE AND STEATITE AREA, LOOKING EAST.

11. *Duxbury*. Six miles north-northwest in the southeast corner of the town. About one mile long.

12. *Moretown*. Four and a half miles northeast, just south of the Winooski River. Length indefinite.

13. *Waterbury*. About six miles farther to the north-northeast, in the northeastern part of the town of Waterbury, is the most typical area of serpentine in Vermont. It is of medium size, about 1,300 feet long and 325 feet wide. It lies in an open pasture as a low hill practically free of vegetation. This feature, in addition to the fact that it is typical of nearly all the other occurrences, led to a detailed study of it. The results are briefly given here, and may be considered in a general way as applying to all the areas mentioned.

Both steatite and serpentine are found here intimately associated, but always separated by a sharp contact. The amount of steatite is relatively greater than that of serpentine; the latter composes the greater part of the west side of the area, but on the east side occurs only as lenses in the steatite. Such lenses have their long axes parallel to the long axis of the whole area, and rise slightly above the steatite, owing to the greater resistance to weathering.

The serpentine varies in color from dark green to light green according to the amount of magnetite present. The two colors may often be seen in the same specimen. When weathered, the serpentine takes on an ash-gray color. This is the typical color on weathered surfaces, except where magnetite is very abundant, which causes a brown color. In addition to magnetite, which is sometimes in small veins but more often disseminated, rhombs of dolomite are common. Veins of talc and of fibrous chrysotile are found in the serpentine, but these are always small. In places the serpentine is sheared; this causes a coarse fibrous structure.

The steatite on the east side extends farther north than the serpentine, and so forms the northern end of the area. When fresh the color of the steatite varies from a light to a dark gray, often with a greenish tinge, but on the weathered surfaces it becomes brown. Magnetite and dolomite are present as well as other impurities. Some of it is fairly pure, and in such places it contains a considerable amount of finely foliated talc. Near the center of the steatite is what appears to be a horse of chlorite schist, completely surrounded by steatite, and carrying chlorite in large deep-green plates. A similar mass of chlorite carrying octahedra of magnetite exists in the Rochester area.

On the west side near the center, the serpentine is in contact with a narrow band of chlorite schist; which in turn is in contact with a highly folded dark schist with layers of granular quartz. The same rocks are found forming the contact on the southwest. Both schists are nearly vertical, and where strikes could be obtained, the schistosity shows evidence of curving around the area of serpentine and steatite. On the east side the schist is only exposed in one place, and here it is badly weathered.

14. *Lowell.* Twenty-five miles north-northeast of Waterbury at "Chrysotile," on the side of Belvidere Mountain. Carries asbestos. Described by Marsters (4) and Richardson (2).

15. *Lowell.* Five and a half miles northeast, near village of Lowell. Large, but length doubtful, width approximately one mile.

16. *Lowell.* A short distance east of the last area. Size doubtful.

Unsuccessful attempts were made to find areas reported in the "Geology of Vermont" in the towns of Newfane, Warren, Waitsfield, Middlesex, Waterville, and Westfield. In the last named town at Hazen's Notch (Loc. 17 on map), serpentine was found, but it was doubtful whether it was in place. In the others no serpentine was found where indicated on the map, but the rock may nevertheless exist in these places, as in no case was more than one day spent hunting for a locality. No attempt was made to visit the areas reported in Enosburg, Montgomery, and Richford.

PETROGRAPHY.

A study was made of sixty-four thin sections of serpentine from the different localities. The specimens were selected to show as much variety as possible; from the contacts, the center, the north and south ends, etc. When examined, however, they showed a remarkable uniformity. Alteration from the parent rock has nearly always been complete; only in a few cases were any original minerals present. Normally about three quarters of the section is serpentine either platy or granular, and rarely fibrous. It is generally colorless but has occasionally a light greenish-yellow tint. Unfortunately no traces of any pseudomorphic forms are present, and it is seldom that the grains of magnetite are arranged so as to suggest any of the original crystal lines.

Olivine is present in sixteen of the sections, occasionally in large prisms, but more often in groups of rounded fragments, or scattered small grains, in various stages of alteration to serpentine. In two cases the olivine showed a perfect development of cleavage; in all the others only the characteristic irregular fracturing is seen. The presence of olivine is of the highest importance in determining the origin of serpentine. Equally interesting, however, is the lack of talc in all sections containing olivine.

Monoclinic pyroxene was identified in three cases, and probably exists in others. Owing to its method of occurrence it could not always be distinguished with certainty from olivine. It

shows no crystal form, but when cleavage is present can be distinguished from olivine by its extinction angle. Pyroxene is never present in large amounts, but since, like the olivine, it has altered to serpentine, it is possible that it was formerly fairly abundant.

Magnetite occurs in widely varying amounts in all the sections; sometimes as octahedra, but more often as irregular grains or aggregates. Occasionally the arrangement of these grains suggests that the magnetite is an alteration product from some other mineral; some of it, however, is without doubt original. When dolomite is present in the section, it often surrounds the magnetite. Similarly the magnetite is sometimes surrounded by serpentine composed of radially arranged fibers.

Chromite was distinguished in twelve sections, its presence being first detected by a very dark brown color in the thinner parts of a section. In other parts it might easily be mistaken for magnetite except for the fact that in these rocks it usually occurs in larger and more irregular masses. Its presence was also established by chemical test. No talc is present in the sections containing chromite.

Dolomite is common either as rhombs of varying size, or in more massive form; in the latter case it may constitute a very considerable part of the whole section. In one or the other of these two forms it was seen in thirty-seven sections. It is usually colorless, shows typical cleavage, and often contains small grains of magnetite as inclusions. The distinction of dolomite from calcite was made by chemical test.

Talc is found in twenty sections as small colorless plates. These are often scattered throughout the whole section. Where talc is very abundant the rock is more properly classed as steatite.

Cubes of pyrite are present in fourteen sections, but never are more than two or three small crystals found in the same section. The minerals surrounding it are usually stained by its partial alteration to limonite.

ANALYSES.

The following analyses give the composition of the Vermont serpentine, and show how it compares with that from Georgia and Quebec. For No. 1, my thanks are due to Mr. R. E. Somers.

No. 1. Serpentine from Dover, Vermont.

No. 2. Serpentine from Belvidere Mountain, Vermont. Analysis from V. F. Marsters (4).

No. 3. Same as No. 2.

No. 4. Serpentine from Corundum Hill, Georgia. From Pratt and Lewis (8).

No. 5. Serpentine from Thetford, Quebec. From F. Cirkel (9).

	1	2	3	4	5
SiO_2	38.10	40.21	40.82	41.90	40.76
Al_2O_3	2.31	5.73	7.67	0.71	——
Fe_2O_3	2.70			0.91	3.05
FeO	3.48	——	——	——	0.49
MnO	0.11	——	——	——	——
MgO	42.04	40.98	38.40	40.16	42.32
K_2O	0.15	——	——	——	——
Na_2O	0.19	——	——	——	——
CaO	——	0.82	1.37	——	0.35
H_2O	11.45	12.68	12.41	16.16	13.60
NiO	——	——	——	0.10	——
Total	100.53	100.42	100.67	99.94	100.57

The Vermont serpentine, as is seen from these analyses, is fairly uniform. The Dover rock is slightly lower in silica and higher in magnesia than that from the northern part of the State. The latter, moreover, contains a small amount of lime not found in the southern occurrence. If compared with that from Georgia, the Vermont rock is seen to contain more alumina and iron oxide, but less water. The Canadian serpentine has evidently a lack of alumina; otherwise it closely resembles the Vermont rock.

ORIGIN.

The mineralogical composition of these serpentines strongly suggests that they are the alteration product of a basic igneous rock. The presence of original olivine in a large number of specimens, without any trace of pyroxene, makes it seem that the parent rock was almost a pure dunite; for if much pyroxene had originally been present, it would in all probability have resisted alteration as long as the olivine. In the cases where pyroxene does occur it may be inferred that the parent rock was less basic, probably an ordinary peridotite.

The alteration of peridotite to serpentine is caused by hydration. The source of the water may be either magmatic or meteoric. If magmatic, some later intrusive which supplied the water should be found either cutting the serpentine, or in its immediate vicinity. Such intrusives are not found, and consequently the theory of meteoric origin must be relied on to account for water.[1] In support of this it may be pointed out that ground water contains carbon dioxide and oxygen, which acting on the iron and magnesium liberated by the change from peridotite to serpentine, would help to explain the existence of so much magnetite and dolomite in the serpentine. The alteration must have taken place at some depth, as ordinary surface weathering of peridotite would merely cause decomposition and disintegration, the products of which would tend to be simpler compounds such as carbonates, silica, and limonite, rather than the complex hydrous silicate forming serpentine.

[1] Since this paper was originally published, Prof. C. H. Richardson has informed me that in Troy the steatite is cut by diabase, and has been materially altered by the later intrusive. He also calls attention to the western belt of serpentine in the same town (not visited by the writer) where steatite occurs flanking the serpentine on the west and east sides.

No very strong evidence can be obtained in regard to the origin of the serpentine from the forms in which it occurs. The most that can be said is that they are concordant with the existing schistosity. If the schistosity corresponds to the original bedding planes, they were true concordant intrusions. They do not, however, resemble sills or laccoliths, nor is it easy to imagine how they could have been changed from such to their present form, even as a result of later mountain building. The size of some of the partially altered grains of olivine implies that the intrusions did not occur as surface flows but have been revealed by long continued erosion. If the schistosity does not correspond to the original planes, they may have been volcanic necks which have been flattened out into lenses by lateral pressure or by tectonic forces, or in the case of the longer masses they may have been large dikes. Such relations are, however, improbable, and as practically all the areas are lenticular, no matter where intercepted by the plane of erosion, they may best be called pipes. These pipes of intrusive material, it may be supposed, were forced in along some plane of weakness subsequent to a period of orogenic disturbance.

The areas in the northern part of the State have been described as batholiths, bosses, sills, and lenses. Of these, the first two should have cross-cutting relations with the country rock. This has not been definitely shown, and hence their size is the only evidence in favor of these forms. The sills and lenses are probably not very different from the forms further south.

AGE.

The schistose structure of the rocks in which the serpentine occurs was caused by deformation during the Ordovician period. The serpentine does not appear to have suffered the same amount of metamorphism,—a fact that suggests it was intruded since that time. If this were so the shearing, often found in the serpentines, might be explained by the disturbances of a milder nature which took place during the Permian. This taken in connection with the fact that the serpentine of Manhattan Island and vicinity has been definitely shown to be older than the Triassic sandstone (10), would lead to placing the age of the serpentine as post-Ordovician and pre-Mesazoic. However, inasmuch as the shearing may equally well be attributed to expansion caused by hydration during alteration, and owing to the fact that in northern Vermont, (at a locality not visited by the writer), the serpentine does not cut the Irasburg conglomerate (Lower Ordovician) (2), it is much more probable that a pre-Ordovician age must be assigned to the serpentine.

LINEAR DISTRIBUTION.

The reasons for the very striking linear distribution of the areas of serpentine can only be very vaguely stated. The presence of such a large body of magma as must be supposed to have existed at one time beneath this region, must first be admitted. Then there must have been some condition in the overlying rocks that offered less resistance to intrusion along this line than elsewhere. Inasmuch as this line is parallel to the Green Mountains, as well as to the foliation of the schists, the explanation must be looked for in connection with these structures. The forces which produced these structures may have developed a zone of lessened pressure into which the magma would find easy access, especially along some bedding plane in this zone, if such a plane were present. If the intrusion forcing its way along such a plane, found the resistance less in some places than in others, it would not enter as a continuous sheet, but would select the places where the resistance was least. Under such conditions we might expect to find pipe-like intrusions along a contact plane between two formations. Such seems to be the case of the serpentines in Vermont.

COMPARISON WITH OTHER AREAS IN UNITED STATES AND CANADA.

The serpentine of Vermont does not differ materially from that in the same belt occurring further south or in Canada. The composition was seen on a previous page to be nearly the same in Georgia, Vermont, and Quebec. Mineralogically the Vermont rock lacks the corundum found in that from Georgia, and contains only small amounts of the asbestos so abundant in the Canadian region.

In regard to alteration, the Vermont rock is more uniformly altered than that in the southern States, and in most cases is in a more advanced stage. Areas of only partially altered peridotite do not exist here, while in the south such occurrences are numerous. In Quebec the stage of alteration is in some places about the same as in Vermont, while in others unaltered peridotite still exists. The form and size of the intrusions in Vermont are similar to those of the southern ones, but they are not as large as some of those in Canada.

RELATIONS OF SERPENTINES AND STEATITE.

It has been seen that steatite occurs very frequently with the serpentine, either intimately associated in the same outcrop, or in a similar occurrence near by. This suggests that the origin of the steatite is much the same as that of the serpentine, and that the two are probably very closely related. The difference in composition between the minerals—talc and serpentine—is merely in the amount of silica and water. This difference may be due either to some slight original difference in the rock from which the steatite has been altered, or to some difference in the conditions of alteration which allowed both minerals to be formed from the same origin.

The steatite occurrences are more numerous than the serpentine, but except for the fact that they are found in a slightly wider band, their distribution as well as their form is much the same. They are, therefore, without doubt due to the alteration of a basic igneous rock in much the same way as is serpentine. In a few places the relations between the two rocks suggest that the parent rock of the steatite was an earlier intrusive than that of the serpentine. This feature is best seen at Waterbury where the serpentine occurs as lenses with sharp contacts in the steatite. The existence of sharp contacts and the distribution of so many lenses of serpentine throughout the steatite make it seem improbable that the two kinds of rock were produced by different alteration from the same original intrusive. The earlier intrusive may have been a pyroxenite containing considerable pyroxene which altered to steatite. The later intrusive was more basic due to further differentiation and may have been a relatively pure dunite which subsequently was changed to serpentine. In this connection it is interesting to note that an area of unaltered dunite exists further south in Massachusetts at Cheshire.

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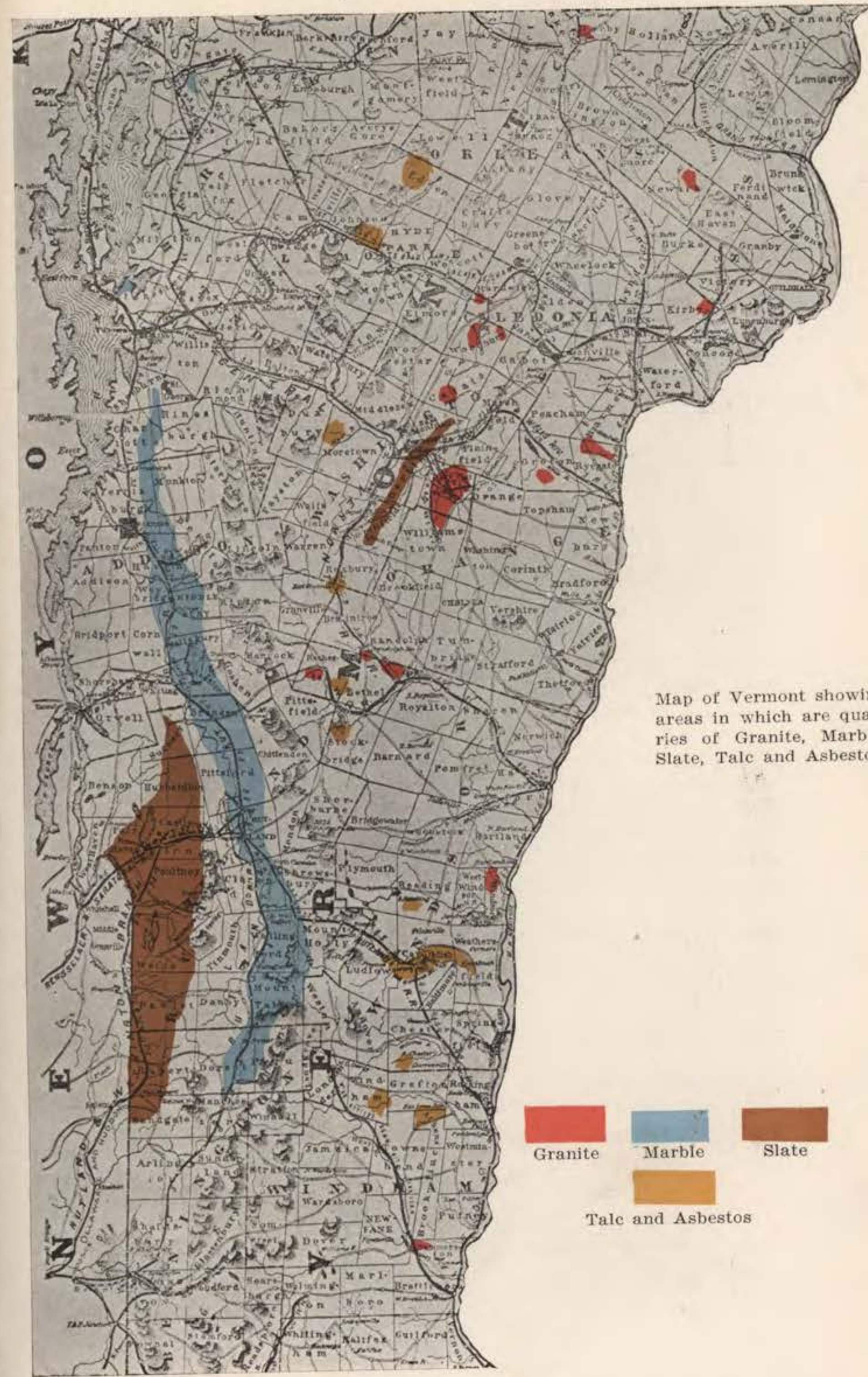

Map of Vermont showing areas in which are quarries of Granite, Marble, Slate, Talc and Asbestos.

MINERAL RESOURCES.

G. H. Perkins.

There has been no very great change in the output of Building Stone since the last Report was issued. The great European war has so far affected the building business that the demand for material for large and fine structures has been less than in years immediately preceding this. As it always must be, the marble, granite and slate produced by the state far outweigh in importance all other mineral output. Indeed there is little else than these, except the sales of lime at the several kilns where limestone is burned.

As Mr. Smith of the Vermont Marble Company has given on foregoing pages a full account of the new plant for manufacturing lime which has been built at West Rutland, further mention of this industry is not needed here. The total value of lime sold for different purposes, chemical, agricultural and structural, is about $200,000 annually and with new plants this will be increased in the future.

An article on Copper Mining in Vermont by Professor Jacobs in this Report makes further reference to this industry unnecessary. So too of Talc and Serpentine which Professor Jacobs has thoroughly treated in his article on that subject. The map Plate LXXIV shows the general distribution of the Marble, Granite and Slate quarries and Talc mines.

I have not been able to obtain accurate figures expressing the value of the building, monumental and ornamental stone sold in Vermont during the years 1915-1916, but approximately the amounts are are follows:

Granite	$6,000,000
Marble	4,000,000
Slate	1,200,000
	$11,200,000

Adding to this the production of Lime $200,000, Limestone $12,000, Clays, $100,000, Ocher, etc., $10,000 we find that the total mineral production of Vermont amounts to $11,500,000. As heretofore, Vermont leads the world in the amount of Granite and Marble sold as well as in quality and variety and is second to Pennsylvania only in the sales of Slate. The number of granite and slate companies has decreased during the last four or five years.

GRANITE.

The granite industry has had some fluctuations during the past two years, but on the whole the business has retained its prosperous growth of the last ten years. The following list which has been recently revised by Mr. H. P. Hinman, Secretary of the Barre Granite Manufacturers Association, will be found useful in this connection.

LIST OF GRANITE COMPANIES IN VERMONT AT PRESENT IN OPERATION.

BARRE AND VICINITY.

Barclay Brothers, Barre, Q. C.
Barre Medium Granite Co., C.
Barre White Granite Co., Barre, Q.
Barre Granite Quarry Co., Barre, Q.
Beck & Beck, Barre, C.
Bianchi, Charles & Son, Barre, C.
Bond, Geo. E. & Co., Barre, Q. C.
Boutwell-Milne-Varnum Co., Barre, Q. C.
Brown, Carroll & Co., Barre.
Brown, John & Co., Barre, C.
Brusa Brothers, Barre, C.
Bugbee, E. A. & Co., Barre, C.
Burke Brothers, Barre, C.
Canton Brothers, Barre, Q. C.
Carswell-Wetmore Co., Barre.
Central Granite Co., Barre, C.
Chiold Brothers, Barre, C.
Cole, W. & Sons, Barre, C.
Comolli & Co., Barre, C.
Consolidated Quarry Co., Barre, Q. C.
Corskie, J. P. & Son, Barre, C.
Davis Brothers, West Berlin, C.
DeBlois, L. G., Granite, C.
Dessureau & Co., East Barre, C.
Dewey Column and Monumental Works, Barre, C.
Freeman & Wasgatt, Barre, C.
Gasparello Brothers, Barre, C.
Gerrard-Barclay Granite Co., C.
Glysson, E., Barre, C.
Grearson & Lane, Barre, C.
Guidici Brothers & Co., Barre, C.
Harrison Granite Co., Barre, C.
Herbert & Ladrie, Barre, C.
Hoyt & Lebourveau, Barre, C.
Indum, G. E., C.
Johnson & Gustafson, Barre, C.
Jones Brothers' Co., Barre, Q. C.
Jones, A. S., Barre, C.
Jones, W. B., C.
LeClair & McNulty, Barre, C.
Littlejohn, Odgers & Milne, Barre, C.
McDonnell & Sons, Barre, C.
McMillan, C. & Son, Barre, C.
Malnati Brothers, Barre, C.
Marr & Gordon, Barre, C.
Marrion & O'Leary, Barre, C.
Martinson Estate Co., Barre, C.
Milne, Alex, Barre, C.
Newcombe, T. J., Barre, C.
North Barre Granite Co., Barre, C.
Novelli & Calcagni, Barre, C.
Oliver & Co., Barre, C.
Parry & Jones, Barre, C.
Parnigoni Bros., Barre, C.
Passera Bros., Williamstown.
Peerless Granite Co., Barre, C.
Pirie, J. K., Graniteville, Q.
Presbrey-Coykendall Co., Barre, C.
Provost, S. & Son, West Berlin, C.
Rizzi, L. G., Barre, C.
Robertson, J. C., Barre, C.
Robins Brothers, Barre, C.
Ross & Ralph, Barre, C.

Ross & Cassellini, Barre, C.
Roux Granite Co., Barre, C.
Scandia Granite Co., Barre, C.
Sector, James & Co., Barre, C.
Smith, E. L. & Co., Barre, Q. C.
Standard Granite Co., Barre, Q.
Star Granite Co., Barre, C.
Stevens, H. D., Barre, C.
Straiton, George, Barre, C.
Sullivan Eugene, Barre, C.
Valz Granite Co., Barre, C.
Vanetti Granite Co.
Wells-Lamson Quarry Co., Barre, Q.
World Granite Co., East Barre, C.
Young Brothers Co., Barre, C.

MONTPELIER.

Airoli, G. & Co., Montpelier, C.
Aja Granite Co., Montpelier, C.
Bianchi, G. R., Granite Co., Montpelier, C.
Bonazzi & Bonazzi, Montpelier, C.
Bowers, R. C., Granite Co., Montpelier.
Columbian Granite Co., Montpelier, C.
Doucette Brothers, Montpelier, C.
Excelsior Granite Co., Montpelier, C.
Fraser, R. M., Montpelier, C.
Gill, C. P. & Co., Montpelier, C.
Jurras Granite Co., Montpelier, C.
Lillie Granite Co., Montpelier, C.
McGovern Granite Co., Montpelier, C.
Mills & Co., Montpelier, C.
National Granite Co., Montpelier, C.
Patch & Co., Montpelier, Quarry at Adamant.
Sheridan & Poole, Montpelier, C.
Wetmore & Morse Granite Co., Montpelier, Q.

NORTHFIELD AND BETHEL.

Cross Brothers Co., Northfield, C.
Northfield Granite Co., Northfield, C.
Pelaggi, N. & Co., Northfield, C.
Phillips & Slack, Northfield, C.
Woodbury Granite Co., Bethel and Northfield, Q. C.

WATERBURY.

Drew, Daniels Granite Co., Q. C. Quarry at Adamant.
O'Clair, C. L.
Union Granite Co., Waterbury, C.

HARDWICK AND WOODBURY.

American Granite Co., Hardwick, C.
Bailey Bros., Woodbury, Q.
Calderwood & Merriam, Hardwick, C.
Crystal Brook Granite Co., Hardwick, C.
Donald, Wm. B., Hardwick, C.
Emerson & Bond, Hardwick, C.
Eureka Granite Co., Hardwick, C.
Fletcher, E. R., Woodbury, Q.
Hardwick Polishing Co., Hardwick.
Hay, John, Hardwick, C.
James Granite Co., Hardwick, C.
Murch, E. R., Hardwick, C.
Purdy, F. A., Hardwick, C.
Smith, Ashley, Hardwick, C.
Thomas, A. B., Woodbury, Q.
Vermont Quarries Corporation, Woodbury, Q.
West End Granite Co., Hardwick, C.
Woodbury Granite Co., Hardwick. Quarries at Woodbury, Buck Lake and Bethel. Works at Hardwick, Northfield and Bethel.

GROTON AND RYEGATE.

Anderson, Axel, South Ryegate, C.
Augustini, Ryegate.
Beaton, A. T., Ryegate, C.
Beaton, James, Ryegate, C.
Benzie & Company, Groton, C.
Blue Mountain Granite Works, Ryegate, C.
Brock, S. E., Ryegate, C.
Cerutti, C. F., S. Ryegate.
Checchi, A., Groton, C.
Craigie, James, Ryegate, C.
Eliason, C. E., S. Ryegate, C.
Hartz, L., S. Ryegate, C.
Hendry, C. H., Groton, C.
Hosmer Brothers, Groton, C.
Leonard, G., S. Ryegate, C.
McDonald, M. F., Ryegate, C.
Nicolo, T., Ryegate.
Rosa Brothers, Ryegate, Q. C.
Ryegate Granite Works, Ryegate, Q. C.
Samuelson, H., S. Ryegate, C.
Zambelli, S. Ryegate, C.
Zambion, Peter, S. Ryegate, C.

BARTON.

Barton Granite Co., Q.
Ray, E. F., C.
Ward & Company, C.

OTHER PARTS OF THE STATE.

Ayer, E. S., West Danville, C.
Calais Granite Co., Calais, Q.
Chapman, W. J., West Concord, C.
Clark, James, West Dummerston.
Daniels, J. C., West Concord.
Goss, A. J., West Danville, C.
Grant, C. H., Granite Co., Dummerston, Q. C.
Grout Granite Quarry, West Concord, Q.
Haselton, Charles, Beebe Plain, Q.
Kearney Hill Granite Co., West Concord, Q.
Lake Shore Granite Quarry, Adamant, Q.
Newport Granite Co., Albany, N. Y. Quarry at Derby.
Norton, S. B., Beebe Plain, Q.
Stanstead Granite Quarries Co., Beebe Plain, Q.
Tillcrop Granite Co., West Concord, C.
Union Granite Co., Calais, Q.
Union Granite Co., Morrisville, C.
Welch, Joseph, West Concord, C.
Williamson, Harry W., Concord, C.

Granite also occurs in Albany, Newark, Cabot, Lowell, Randolph and some other towns, but is not quarried in these places.

While the granite business has been very good during the two years included in this report, it has become unusually active during the last months of this year, 1916. American Stone Trade, which is mainly a granite paper, says of this "Every sign indicates that the volume of orders * * * * to be placed with manufacturers during November will be the largest of any like period in the history of the industry." The above refers especially to the monument business as the writer is speaking of the Barre district where there is little building granite sold, but we are told that increased activity in the sale of building granite at Hardwick is also encouraging.

MARBLE.

In the Report for 1913-1914 a very full study of the history, methods, extent of the Marble Industry and of the distribution and variety of this stone in Vermont was given and those interested in this subject are referred to this volume. The sales of marble during the past two years have not differed very much from those of years immediately preceding.

The companies at present doing business in Vermont are the following:

Clarendon Marble Company, Clarendon.
Eastman Marble Campany, Rutland.
Manchester Marble Company, East Dorset.
Meadowbrook Marble Company, Brandon.
Middlebury Marble Company, Middlebury.
United Marble Company, Rutland.
Vermont Marble Company, Proctor.

The varieties of stone quarried and sold by each of the above companies is mentioned in the Report referred to above and need not be repeated here.

SLATE.

The slate industry in Vermont still holds its own as second in the country, but it has decreased somewhat though slowly during the past ten years. The demand for roofing slate has always been good, but that for other varieties, what is technically called "mill stock" has been less. The following list of companies is given:

LIST OF VERMONT SLATE COMPANIES.

CASTLETON.

Criterion Slate Company, Hydeville.
Hayes Slate Company, Hydeville.
Hinchey Brothers, Hydeville.
Hinchey, O. & Company, Castleton.
John J. Jones Slate Company, Castleton.
Minogue Brothers & Quinn, Hydeville.
Metalo Slate Company, Hydeville.
Penryn Slate Company, Hydeville.

FAIRHAVEN.

Bedford & Ryan Slate Co., Fair Haven.
Durick & Flannagan, Fair Haven.
Durick & Keenan, Fair Haven.
Durick, Keenan & Flannagan, Fair Haven.
Fair Haven Marbelized Slate Company, Fair Haven.
Jones & Francis, Fair Haven.
McNamara Brothers, Fair Haven.
Mahar Brothers, Fair Haven.
Vermont Unfading Green Slate Company, Fair Haven.
Victor Slate Company, Fair Haven.
Young, A. B., Fair Haven.

GRANVILLE, NEW YORK, QUARRIES IN VERMONT.

Norton Brothers, Granville, N. Y.
Owens, O. W. Sons, Granville, N. Y.
Sheldon, F. C., Granville, N. Y.
Vermont Slate Co., Granville, N. Y.

POULTNEY.

Auld & Conger, Poultney.
Eastern Slate Company, Poultney.
Eureka Slate Co., North Poultney.
Frasier Slate Company, Poultney.
Green Mountain Slate Co., Poultney.
Griffith & Nathanael, Poultney.
Hughes-Snyder Slate Co., Poultney.
Johnson, E. J. Slate Co., Poultney.
Roberts & Rowland, Poultney.
Matthews Slate Company, Poultney.
Parry, Jones & Owens, Poultney.
Poultney Consolidated Slate Company, Poultney.
Rice Brothers, South Poultney.

PAWLET AND WELLS.

Layden & Burdick, West Pawlet.
Hughes, W. H. Slate Company, West Pawlet.
Nelson Bros. & Morow, West Pawlet.
O'Brien Brothers, Wells.
Phoenix Slate Company, West Pawlet.
Rising & Nelson, West Pawlet.
Roberts, G. T., West Pawlet.
Williams, R. Scott, Slate Company, Wells.

CLAYS.

At present there are the following active companies in the State, viz.:

Horn-Crockett Company, Brandon, works at Forestdale.
American Paper Clay Company, Rutland.
Rutland Fire Clay Company, Rutland.
E. L. Sibley, Bennington.
E. F. Rockwood, Bennington.
S. C. Lyon Brothers, Burlington.

The first two and last named produce white clay, the Rutland Fire Clay Company sell a variety of products obtained from several different kinds of clay which they dig. Messrs. Sibley and Rockwood produce yellow clay, ocher.

In all over $100,000 worth of clay is annually sold. This is exclusive of bricks which are made in a number of localities.

INDEX.

Volumes I-X, 1898-1917.