REPORT

OF THE

STATE GEOLOGIST

ON THE

Mineral Industries and Geology of Certain Areas

OF

VERMONT.

1907-1908.

SIXTH OF THIS SERIES.

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LIST OF PLATES.

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FIGURES IN THE TEXT.

STATE OF VERMONT.

OFFICE OF STATE GEOLOGIST.

Burlington, Vt., October 1, 1908.

To His Excellency Fletcher D. Proctor, Governor of Vermont:

Sir: In accordance with Section 279, Statutes of 1900, I herewith present my Sixth Biennial Report as State Geologist. A brief summary of the work which has been carried on in the department of geology during the past two years is given in the introduction. As this indicates, much and valuable assistance has been rendered by several geologists from other states. Some of the most important papers which give the results of this work, as those of Dr. Dale and Mr. Merwin, have been obtained wholly without cost to the state and only nominal compensation has been made to others.

Without this very material assistance it would be quite impossible to present to the people of the state so valuable a series of papers treating of the geology of Vermont as are those included in the present volume unless the geologist had at his disposal a very much larger appropriation than has been available.

The usual routine work of this office, such as extensive correspondence, analysis of minerals or ores, investigation of the mineral resources of the state, has been carried forward.

Prominent as Vermont has been for many years as a producer of granite, marble and slate, it has become more so during the last few years. Dealers and builders are sending numerous inquiries as to the different rock products of Vermont and from all over the United States. The geologist has regarded the work of answering as promptly and fully as possible all such requests for information as a most important part of his duties, for it is certain that in this way a constantly increasing market for the varieties of stone which the state can supply may be controlled.

Very respectfully,

GEORGE H. PERKINS,

State Geologist.

Introduction.

It is with much satisfaction that it has been possible to assemble in the following Report, the sixth of the present series, several important articles treating of the geology of different parts of Vermont. After a more full account of the mineral resources of the state in general than has been given heretofore, Dr. T. N. Dale's article on Vermont granites will be found of great value and interest. As the full article will not be published for several months, it is well that through the courtesy of the Director of the U. S. Geological Survey, under which the investigation was carried on, and of Dr. Dale, that an extended abstract, embracing most of the more important points, can be included in this Report.

As stated in the article itself, it has long seemed to the curator of the State Cabinet that the most important specimen which it contains is deserving of greater attention than it has received. Accordingly the article describing and illustrating this specimen, the Fossil Whale, has been prepared and, as during its preparation it was found desirable for the purpose of comparison to study all similar specimens, this has been done so far as practicable, so that the article on Delphinapterus really includes all the Pleistocene Cetacea so far as specimens are found in different museums.

Mr. H. E. Merwin, assistant in geology, Harvard University, was engaged in work on the surface geology of several parts of this state during the summer of 1906 and he has kindly furnished me a copy of the paper giving the results of his investigations in order that it may be published in the present report.

Mr. Merwin's paper was first printed in Bulletin No. 7, Geological Series, Vol. VIII, of the Museum of Comparative Zoölogy, Harvard College, and I am indebted to the museum for the illustrations which accompany the paper.

From this article and those by Professor Hitchcock published in the Fifth Report a large amount of new and interesting information concerning the conditions which prevailed during and immediately after glacial times may be obtained. Following this article is an important discussion of the geology of the Hanover Quadrangle, by Professor C. H. Hitchcock. As the larger part of this quadrangle of over a hundred square miles is in Vermont, and that which is on the New Hampshire side of the line presents substantially the same features as those found in neighboring parts of Vermont, it is eminently fitting that Professor Hitchcock's investigations should be published in this Report. The results presented in this paper are not merely those obtained while the author has been working, in coöperation with the Vermont Survey, but many of them have come from years of study of the region which is included in this quadrangle.

Professor Seely, who in previous Reports has contributed several papers on fossils of the Chazy and Beekmantown, has furnished for this volume a short account of certain curious structures found in *Strephochetus* of the Chazy.

In accordance with the plan stated in previous Reports, according to which it is proposed to take up in succession from north southwards the western portion of Vermont, in which the rocks are largely beds of Cambrian and Ordovician, the results of work in Franklin and Chittenden counties are given in this volume so far as they have been reached. Franklin County was partially studied several years ago and some report of the work may be found in the volume immediately preceding this, and the geology of Grand Isle County in the Fourth Report. The study of the geology of St. Albans by Mr. Edson in the Fifth Report is supplemented in this by a similar study of Swanton, and it is expected that Mr. Edson will be able to carry his exploration over other towns in Franklin County. Indeed a beginning in this direction has already been made.

The work of the Geologist in Chittenden County, as will be seen from the article in which this region is taken up, is not complete, but a considerable beginning has been made, and it is planned to continue this and carry the work on into Addison County before the publication of the next Report.

The last article in the volume is a continuation of work carried on at the request of the Geologist in northern and northeastern Vermont by Professor C. H. Richardson. The area discussed by Professor Richardson presents many difficulties, as does that considered by Professor Hitchcock, on account of the highly metamorphic and disturbed condition of the rocks, and for this reason the reports of these investigators are of much value. Perhaps it will be worth while to

say that in preparing this Report, as has also been true of those which have already been issued, the Geologist has endeavored to have regard to the needs not only, nor mainly, of geologists, but of the people of the state, and especially of the teachers and pupils in the schools. That is to say, it has been his desire that these Reports may not only present such results of scientific investigation as would be useful to trained geologists, but also to so state these results that the statement should have educational value to the untrained in scientific terminology. This may explain the presence of some discussions and the mode in which some facts are given in portions of the Reports.

MINERAL RESOURCES.

The increase in the extent and production of the quarries of the state which was dwelt upon in the Report of 1904–6 has continued since that report was issued. The conditions which then prevailed have not materially changed. Necessarily there have been changes in the management, productiveness, character of product and methods of working. This must always be true if there is progress and development.

It seems to be generally admitted that the cost of producing any sort of stone has increased during the last few years, and as a consequence of this the price of all kinds of stone must rise.

Notwithstanding this, it appears to be true that stone, especially marble and granite and to some extent slate, is more largely used in the outside construction of buildings as well as for interior finish than ever before. It is only a few years since it was quite uncommon, even when a costly building was erected, that stone of any sort was used in the interior. Now, it is not common to find a large public building in which there is not panelling, wainscoting and other finish wholly of stone. The same is also true of most of the larger business or apartment houses.

According to recent statistics gathered by the United States officials, over $20,000,000 worth of stone, mostly marble and granite, is used in buildings annually. Nearly as much, in value, is used as crushed stone for concrete and road material, including railroad ballast. The total value of marble, granite, limestone and sandstone produced annually in the United States is between $60,000,000 and $70,000,000. In 1906 it was $66,378,748, according to the reports of the U. S. Geological Survey. Of this Vermont produced $7,526,466, or 11.34 per cent of the whole. Pennsylvania alone exceeded this amount. In this connection it may be noticed that Vermont produces only an insignificant amount of crushed stone, its product being mostly of finer sorts used in buildings and monuments.

The value of crushed stone sold in this state in 1906 was little over $4,000, while that from Pennsylvania exceeded $500,000. These relations are reversed when monumental and ornamental stone is considered. Vermont here leads by a wide margin. It is scarcely necessary to state that Vermont produces mainly marble, granite and slate, the production of sandstone and limestone being relatively small. In many other states, however, these kinds of stone form the chief product.

The total value of all kinds of stone quarried in Vermont, marble, granite, slate, limestone, sandstone, is not far from $10,000,000. The other mineral products of Vermont are talc, asbestos, soapstone, kaolin, fire clay, and of metals a small amount of silver and copper. Each of these is taken up later.

Before taking up in detail the different kinds of stone produced in Vermont it may not be without interest to some if a statement is made respecting the exhibit of building and ornamental stone and minerals which was made by the state in the Mines Building at the Jamestown Exposition of 1907.

The commission appointed to arrange and direct the exhibit of Vermont products at the Jamestown Exposition desired that the stone industry, which has become so important a part of the business of the state, should be well represented. Accordingly they secured an area of 900 square feet in a very conspicuous part of the large building devoted to Mines and Metallurgy.

The commission requested the State Geologist to collect and forward to Jamestown in time for the opening of the Exposition a complete series of the building and ornamental stone quarried and sold in the state, and also such other specimens as would be appropriately placed with them. The time for gathering such a collection as would adequately represent the mineral industries of Vermont was much less than might have been wished for, and personal visits to any number of quarries were quite out of the range of possibilities. All that could be done was to send letters to as many of the companies quarrying and manufacturing stone as could readily be reached, and place notices in the leading state papers. This was done and it is supposed that everyone in the state who had any especial interest in this part of the Exposition was notified of the opportunity.

It was not intended to urge any company to make an exhibition, but simply to present to all this opportunity of placing their work before the public. A large majority of the companies doing any considerable business of this sort in the state responded promptly. Some, for reasons sufficient to themselves, did not consider it best to make any exhibit and therefore sent no specimens. Others sent such liberal series of samples that the allotted space was completely filled, and when arranged at Jamestown the whole exhibit was declared by wholly disinterested persons to be highly creditable to Vermont. While at Chicago and St. Louis individual companies made larger exhibits of marble, granite and slate, I do not think that at any previous exposition has there been so large a number of varieties of these materials shown. Indeed, this collection at Jamestown was, I am sure, a revelation to many Vermonters of the extent and variety of the stone industry and its products, as it has developed during the last ten or twenty years in this state. It was not at all the design of those concerned in arranging the display to do anything more than make as ample a showing as possible of the materials quarried and wrought in the state. Fine carving or anything out of the ordinary product of quarries and mills was not sought and very little of such work was shown in the Vermont space. The variety, beauty and quality of the stone itself was to be seen rather than the skill of the workman.

For this reason certain definite styles and sizes were suggested to those intending to furnish specimens of their stone, and in nearly all cases the suggestions were followed. These suggestions were as follows: That building and monumental stone be prepared in eight-inch cubes, one face polished, one fine hammered, one coarse hammered, one rock face and the other faces as the exhibitor chose. Stone especially fitted for interior work, such as much of the marble, was to be gotten out in slabs one inch thick and either one foot square or one foot wide and two feet long, one face to be polished. Slate, on account of its very numerous and varied uses, was excepted from the above rule and was received in any form or size that the exhibitors determined. Several granite manufacturers also wished to show, usually in addition to the eight-inch cube, a piece that allowed greater extent of surface, and sent pieces two feet long, one foot wide and three inches thick, one face being polished. In one case a rather elaborate carving surmounted the block of granite and this was acceptable as it showed the manner in which granite could take fine carving, though much of this sort of work would not have been received. In addition to recently quarried specimens by which the present product of our quarries could be seen, it was thought best to complete the Vermont stone series by taking from the State Cabinet such samples as differed in one way or another from those furnished by the various quarrying firms. A few of the more characteristic ores and minerals and some of the most important fossils were also sent.

The entire collection which was exhibited contained sixty-nine samples of marble in polished slabs, fourteen in eight-inch cubes and twelve in smaller cubes, showing about fifty different varieties.

Of granite, of necessity a much smaller variety was shown as this stone, though varying somewhat in shade and texture in different quarries, or even in different parts of the same quarry, yet with the exception of the white Bethel stone, all varieties have a general resemblance. There were at Jamestown fourteen eight-inch cubes, six slabs and two still larger blocks. The slate companies entered into the plan of the exhibit much less cordially than the other stone working firms, and only a few had any exhibit. Still the specimens shown by these represented all the varieties worked in the state, so that even here the exhibit was measurably complete.

There were several eight-inch cubes, a number of slabs of different sizes, to show the structural use of this material, many samples of roofing slate of various sizes, as well as numerous smaller blocks and pieces and a few samples of marbleized slate.

In addition to these materials there were cubes of soapstone, pieces of talc, specimens of iron and copper ores and other minerals and fossils.

At the request of the commission, the Geologist went to the Exposition grounds just before the formal opening and saw that specimens were properly placed. By the orders of the commission several handsome glass-topped cases and large tables without cases had been sent on, and a large pyramid of steps had been constructed in the middle of the allotted space. In and on these all the above named specimens were arranged. Plainly printed labels were placed near the specimens, giving the name, firm by whom sent and location of quarry. On the wall behind the space maps, photographs of quarries and other illustrative material was hung. Through the generosity of the Vermont Marble Company, a sufficient number of turned marble posts were provided. The space secured by the Vermont commission was located on a corner with aisles on two sides and the boundary of the space along these aisles was marked by these posts connected by a heavy cord. The outside wall of the building formed the background of the space and against a portion of this was placed a fine wainscoting of the red and white Champlain marble, bordered by strips of the Roxbury Verde Antique, also given by the Vermont Marble Company. These gifts not only supplied additional samples of Vermont marble, but added greatly to the general appearance of the exhibit.

Partly by way of making suitable acknowledgement to those stone working firms which responded to the invitation of the commission to supply samples of their products which should make more creditable the whole state exhibit, and partly for the convenience of those who may like to know something of the character and variety of the stone quarried in Vermont, the following list is given.

LIST OF SPECIMENS OF BUILDING AND ORNAMENTAL STONE EXHIBITED BY THE STATE OF VERMONT AT THE JAMESTOWN EXPOSITION.

In addition to the marble for finishing the Vermont space which has just been mentioned, the Vermont Marble Company sent twenty-three pieces each 24 x 12 x 1 inch and four eight-inch cubes of the following varieties:

A. Rutland Building, quarried at West Rutland.
B. Rutland Building, quarried at West Rutland.
Pittsford Valley, quarried at Pittsford.
Gray Building, quarried at West Rutland.
Light Sutherland Falls, quarried at Proctor.
Extra Dark Rutland Blue, quarried at West Rutland.
Dark Vein Esperanza Blue, quarried at West Rutland.
Ruvaro, quarried at Monkton.
Rubio, quarried at West Rutland.
Listavena, quarried at West Rutland.
Pink Listavena, quarried at West Rutland.
Brocadillo, quarried at West Rutland.
Verdoso, quarried at West Rutland.
Olivo, quarried at West Rutland.
Dove Blue, quarried at West Rutland.
Second Statuary Rutland, quarried at West Rutland.
Best Light Cloud Rutland, quarried at West Rutland.
Light Cloud Rutland, quarried at West Rutland.
First Quality Pittsford Valley, quarried at Pittsford.
American Pavonazzo, quarried at West Rutland.

American Yellow Pavonazzo, quarried at West Rutland.
Livido, quarried at West Rutland.

The Rutland-Florence Marble Company sent twelve samples. Ten of these were 24 x 12 x 1; two eight-inch cubes:

Extra Dark Mottled True Blue, quarried at West Rutland.
Extra Dark Vein True Blue, quarried at West Rutland.
Dark Vein True Blue, quarried at West Rutland.
Florentine Blue, quarried at Fowler.
Florence, quarried at Fowler.
Light Florence, quarried at Fowler.
Dark Florence, quarried at Fowler.
Pittsford Italian, quarried at Fowler.
Blue Building, quarried at Fowler.
Light Pink Shell, quarried at Bluff Point, N. Y.
Dark Pink Shell, quarried at Bluff Point.
Gray Shell, quarried at Bluff Point.

The Columbian Marble Company sent eight varieties. Six of these were pieces 12 x 12 x 1; two eight-inch cubes:

Italio, quarried at Proctor.
Extra Dark Royal Blue, quarried at Pittsford.
Verdura, quarried at West Rutland.
Moss Vein, quarried at Proctor.
White Rutland, quarried at West Rutland.
Columbian Listavena, quarried at West Rutland.
Light Columbian Building, quarried at Proctor.
White Rutland Building, quarried at Proctor.

The Barney Marble Company sent seven varieties in pieces 12 x 12:

Lyonnaise, quarried at Swanton.
Olivo, quarried at Swanton.
Oriental, quarried at Swanton.
Jasper, quarried at Swanton.
Royal Red, quarried at Swanton.
Verde Antique, quarried at Roxbury.
Swanton Black, quarried at Isle La Motte.

To supplement the above varieties there were sent from the state cabinet the following:

Fisk Black, quarried at Isle La Motte.
Fisk Gray, quarried at Isle La Motte.
Brandon Italian, quarried at Brandon by the Brandon-Italian Marble Company.
Pearl, quarried at Brandon.
Bardillo, quarried at Brandon.
Corona, quarried at Brandon.
Thirteen varieties, quarried at Mallets Bay by the Wakefield Marble Company.
Mantel shelf of Champlain marble, quarried on the Manwell farm, Burlington, sent by Mrs. A. B. Kingsland.

Samples of Vermont granite were sent by several companies as follows:

Green granite, quarried on Mt. Ascutney, Windsor, by the Enright Granite Company; two eight-inch cubes.
Green granite, quarried on Mt. Ascutney by the Norcross Windsor Green Granite Company; eight-inch cube.
Gray granite, quarried at Dummerston by the G. E. Lyon Granite Company; eight-inch cube.
Granite, Arnold ledge, Hardwick, state cabinet; eight-inch cube.
Gray granite, quarried at Woodbury by the Woodbury Granite Company; eight-inch cube.
White Bethel granite, quarried at Bethel by the Woodbury Granite Company; eight-inch cube.
Medium Barre granite, Barclay Brothers' Granite Company; eight-inch cube.
Dark Barre granite, Boutwell-Milne-Varnum Granite Company; 24 x 12 x 3.
Extra Dark Barre granite, by Jones Brothers' Granite Company; eight-inch cube.
Light Medium Barre granite, Jones Brothers; eight-inch cube.
White Barre granite, Jones Brothers; eight-inch cube.
Medium Barre granite, piece 24 x 12 x 3 inches, Wetmore and Morse Granite Company.
Medium Barre granite, eight-inch cube, Granite City Quarry Company.
Light Gray granite, quarried at Randolph by A. H. Beedle.
Dark Barre granite, piece 24 x 12 x 3, Moore Brothers.
Medium Gray granite, Patch and Company; eight-inch cube.

Medium granite, quarried at Derby, Newport Granite Company; eight-inch cube.

Dark Barre, 24 x 12 x 3 inches, E. L. Smith and Company.

Dark Barre granite, Consolidated Granite Company.

As has been noticed only a few of the slate companies sent samples of their stone. The following were exhibited:

Roofing slate, a series of different sizes, quarried at Northfield by the Vermont Black Slate Company.

Black slate, piece 24 x 12 x 3 inches, Northfield, Vermont Black Slate Company.

Purple slate, eight-inch cube, Poultney, State Cabinet.

Sea Green slate, Poultney, two eight-inch cubes, State Cabinet.

Unfading Green slate, Fair Haven, Vermont Unfading Green Slate Company; assortment of roofing slates and blocks of various sizes.

Marbleized slate, four small slabs, Vermont Unfading Green Slate.

Sea Green slate, West Pawlet, Rising and Nelson Slate Company; assortment of roofing slates.

Green and roofing slate, also Purple roofing slate, Poultney, Matthews Slate Company.

Steatite, eight-inch cubes, from Chester, Grafton and Rochester, State Cabinet.

Talc, large mass, Johnson, American Mineral Company.

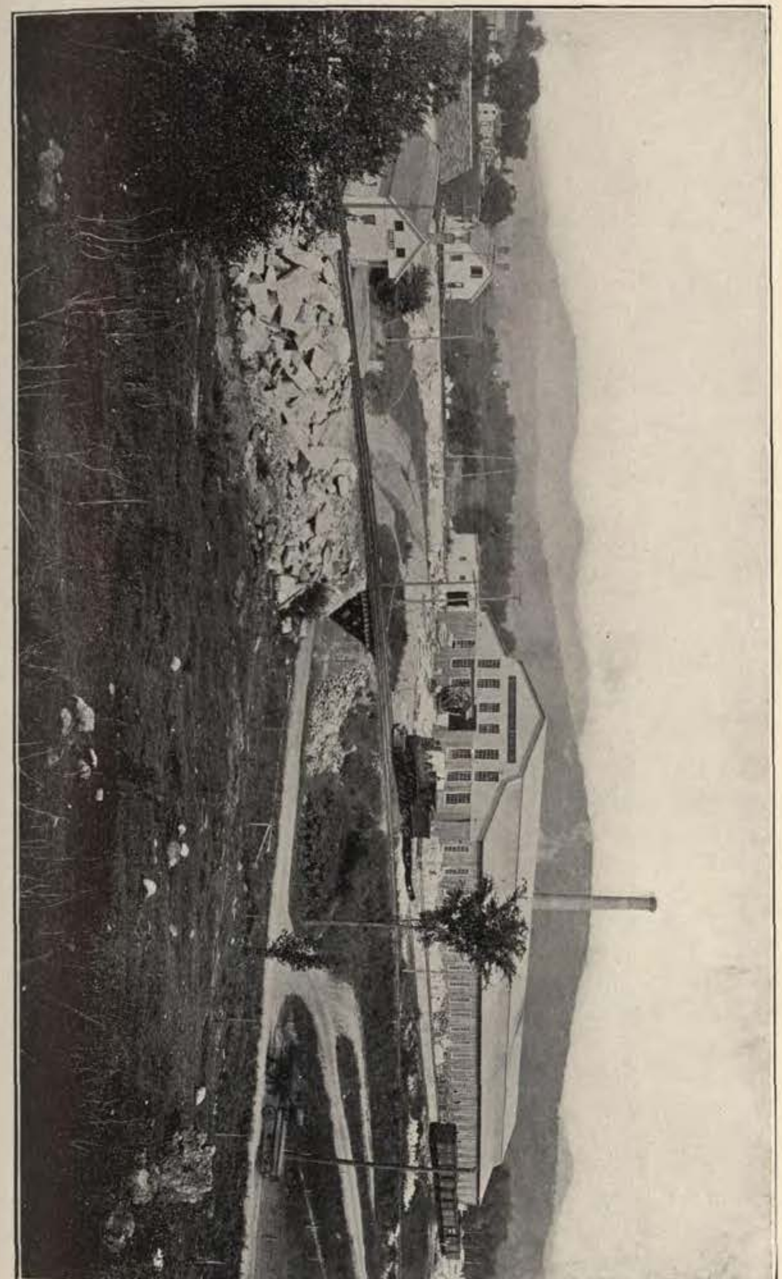
Chrysotile asbestos, Lowell, M. E. Tucker. Specimens from mines now worked by the Lowell Lumber and Asbestos Company.

In addition to the above there were sent from the State Cabinet a considerable number of specimens, some of them of large size, of copper and iron ores, various characteristic minerals and fossils.

There were also a dozen or more large frames containing photographs of quarries or other scenes connected with the stone industries of the state.

It is much to be regretted that all the stone quarrying or working companies in the state could not have been represented. Some, though only a few, of the specimens sent to the Exposition, failed to reach their destination. Nearly all the samples contributed by the above named companies were finally returned to the State Cabinet, to which they were given by the exhibitors and where they may be seen.

PLATE I.



Rutland-Florence Marble Mill, Fowler, Vt.

Perhaps it should be noted that the names given in the foregoing list are the ordinary trade names under which the different sorts of stone are commonly sold. It may also be noticed that a few of the specimens of marble and granite sent from the State Cabinet came from quarries not now worked, but they represent varieties found in the state and such as may at any time be worked and put on the market.

Further remarks upon many of the varieties of stone enumerated will be given in following pages.

As has already been noticed, there has been advance in all respects in the stone industries of Vermont. This is notwithstanding the fact that both the granite and slate business have suffered from strikes during the year. In the granite industry the strike of six weeks' duration does not appear to have seriously affected the sum total of the year's work, though probably it has to some extent. The strike in the slate district has been more injurious and prolonged. The effects of this have been disastrous, not only to the slate business, but to all others dependent upon it.

From this general consideration of the mineral industries of Vermont it will be profitable to pass to a more detailed examination of each by itself.

MARBLE.

Vermont has been known as *the* marble producing state since very early times and it still holds the supremacy which it has so long had. In the U. S. Report on Mineral Resources for 1906 the statement is made that "Vermont produces the greater part of the marble of the United States, the value reported by this state in 1906 being $4,576,913, or 60.36 per cent of the total marble output of the United States."

These figures, however, do not express the real supremacy of this state in the marble business, for, as has been noticed in previous reports, if we exclude the coarser kinds of marble, such as can be used only for building, and include the finer grades alone, such as are used for monuments, interior finish, etc., we find a much more striking array of figures. According to the United States statistics as given in *Mineral Resources* for 1906, the total value of the marble used for the purposes named in the United States for the year was $5,787,769. Of this amount Vermont supplied $4,402,924. And it is not only in quality that the Vermont marble stands first, but in is, as is all the Dorset marble, a harder stone of somewhat larger crystallization than the Rutland marbles.

THE NORCROSS-WEST MARBLE COMPANY. The quarries worked by this company are in Dorset and Danby. The marbles are all of the lighter varieties and have been used in buildings more extensively than any other Vermont marble. The company has a large and finely equipped mill at Manchester. This is connected with the Dorset quarries by a railroad six miles long.

ORVILLO MARBLE COMPANY, CLARENDON. I understand that a company of the above name is in operation, but I have received no reply to letters of inquiry.

RALEIGH MARBLE COMPANY. So far as I can learn this company is doing no work at present. The company owns a quarry in Pittsford, but has no mill.

RUTLAND-FLORENCE MARBLE COMPANY. This company has a large and exceedingly well equipped mill at Fowler and another in West Rutland. The company works quarries in Fowler and Pittsford, from which several varieties of marble are obtained. Plates I–IV are furnished by this company and show some of their property. All the machinery and appliances used are of the most improved pattern. Plate I shows the exterior and II the interior of the large mill at Fowler, while III and IV are views of two of the quarries.

STERLING MARBLE COMPANY. Not working any quarries at present.

VERMONT MARBLE COMPANY. Probably no other marble company anywhere at all equals this in size. This alone supplies a not inconsiderable part of the finer grades of this stone used in the United States.

The headquarters of the company are at Proctor and there are branch offices in many of the larger cities of this country and Europe. There are large mills at West Rutland, Center Rutland, Brandon, East Dorset and Beldens, and very extensive works at Proctor. Many of the smaller companies have been consolidated with this and during the past year the well known Columbian Marble Company, having gone into the hands of a receiver, the Vermont Marble Company has leased the entire plant of this company.

As stated in the last Report, quite a number of old quarries that were formerly worked mainly for monumental stock, and not succeeding in producing that profitably were abandoned, have been reopened within the past few years and much good stone found for building or interior work. The application of improved methods has also made it possible to work quarries that did not prove successful under the old methods. The Vermont Marble Company has been especially active in the development of these neglected quarries and is now working a number of them.

Allusion was made in the previous Report to fossils which had appeared in some of the deep layers in the old Ripley quarry of this company. Through the kindness of Mr. Edson of the company, I am able to present an illustration of this marble. No other recognizable fossils except the *Maclurea magna* have been found in any of the Rutland marbles and, so far as I know, these in the Ripley quarry are the only specimens that have been found in the marble. The ground is bluish somewhat mottled with white and the marble is of the variety called Dove Blue Rutland. In Plate V a slab of this is shown reduced to about one fifth natural size.

It is much to be desired that in some way, either by the combined support of the marble and granite companies of the state or by a legislative appropriation, full descriptions of the principal varieties of stone quarried in the state be given with, what is of the greatest importance, colored plates of the various kinds. Without such plates it is quite impossible to convey to one who has never seen the stone itself any adequate idea of its character. Plates can now be made which are very exact representations of any sort of stone. Necessarily, plates of this kind are costly, but as a business venture, I believe that in time it would bring into the state increase of trade far more than sufficient to repay the cost. Several states, as Wisconsin, Maryland and others have already issued such a work. As has been shown, Vermont has much greater reason to publish such an account of its ornamental stone than any other state in the Union.

Meanwhile, not at all as a substitute, but as perhaps of some little value in assisting dealers and all who may be interested in the subject to a better understanding of the characteristics of our marbles, the following descriptions are offered. No one is likely to realize more thoroughly than the author how very insufficient verbal descriptions of different marbles must be. It should also be remembered that in all quarries the varieties do not remain wholly constant. There is some difference as to this in different localities, but as any given mass of stone is quarried into and deeper layers are taken out, the coloration and arrangement of the constituents is almost sure to vary more

PLATE III.

Florentine Blue Quarry, No. 2, Fowler, Vt.

or less. This may happen in passing from one layer to that next below it, or even from the top to the bottom of a single layer. Nevertheless, some varieties have been on the market for many years and it has not been found difficult by the producers to match slabs taken out at one time with those taken at a much later date so nearly that for all practical purposes the two are the same. But this is by no means always the case. For this reason it is not possible to write a description of any given slab or block or layer in a quarry that will be exact for a term of years.

As may easily be supposed, the appearance of many varieties differs greatly, according to the direction which the saws follow in going through the block. In some varieties it does not make a great deal of difference whether the block is sawed across the grain or parallel with it, but in most it does, and in some two quite distinct varieties are, or may be, produced by difference in sawing.

Most of the varieties named are, however, found in the block and appear however the block is cut into slabs.

Indeed, in preparing the following descriptions the writer has in nearly all cases examined the marble not only in the polished slab, but also in the large mass as taken from the quarry and most are easily recognized in the rough block.

Many less common sorts are not mentioned in these accounts, but only such as are ordinarily found ready for sale.

The thanks of the writer are due to many in different marble companies for affording every opportunity for examining the different kinds of marble under their guidance, for making suggestions and for revising the descriptions of those varieties in which they were especially interested. Especially are acknowledgments due to Messrs. Taylor and Edson of the Vermont Marble Company, Mr. Ernest West of the Norcross-West Company, Mr. Lee Hulett of the Columbian Company, Mr. N. B. Mills of the Rutland-Florence Company, Mr. H. D. Bacon of the Brandon-Italian, Mr. M. W. Barney of the Barney Company, for their interest and aid in this work.

BRIEF DESCRIPTIONS OF THE MORE IMPORTANT VARIETIES OF THE MARBLES OF VERMONT.

For greater convenience of reference the varieties described below are classed as *Light, Dark* and *Fancy*.

It need hardly be said that these classes are quite arbitrary, and that no such classification is recognized in trade. As will be seen the arrangement is alphabetical.

As may be imagined, many of these varieties grade more or less completely into each other and the line of distinction between them cannot be drawn except arbitrarily for convenience. So, too, some of the lighter examples of dark varieties may be as light as some of the darker specimens of the light kinds. Perhaps the grouping is too arbitrary to be of any value.

The ordinary trade names are used in all cases.

LIGHT MARBLES.

Best Light Cloud Rutland.—This is a very light marble, being mostly white with only quite indistinct veinings. These show very little except on a polished surface. When hammered or sawed the stone is nearly pure white. It is quarried at West Rutland by the Vermont Marble Company.

Blue Building.—This, while used mainly as a building stone, may be polished and used for paneling or other interior finish. It is in general of a bluish or grayish blue shade, more or less thickly covered with white or whitish spots and here and there interlaced by white veins.

It is a handsome, moderately dark stone and in different specimens would be classed now as a light, now as a dark marble, though never very dark. It is quarried at Fowler by the Rutland-Florence Company.

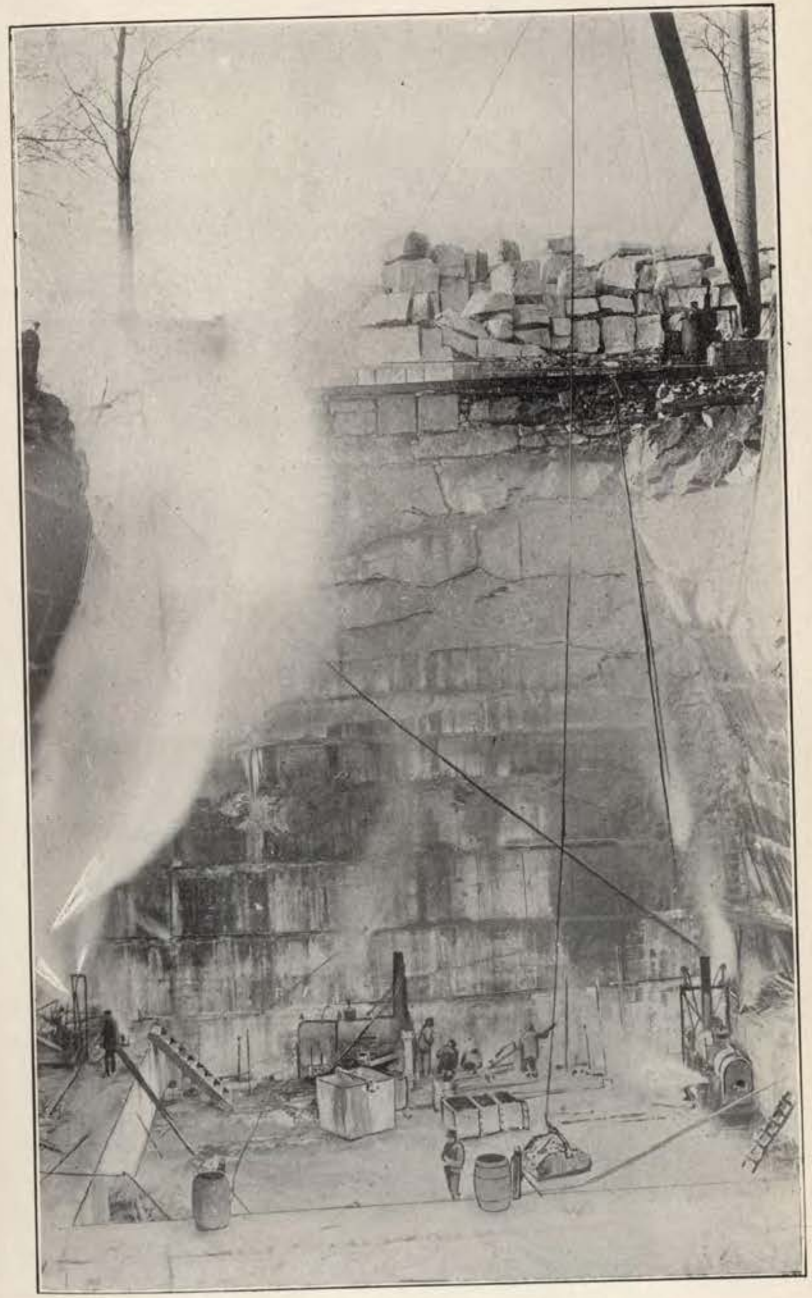
Brandon-Italian.—As the name indicates, this marble closely resembles the ordinary veined imported Italian. In this, as it is scarcely necessary to state, the general ground is white, through this there run not very distinct, dark bluish veins, or lines, or sometimes spots or blotches.

These are usually wavy and irregular. Of course those pieces in which the veins are few and indefinite are very light.

Quarried at Brandon by the Brandon-Italian Marble Company. The quarry from which this variety is taken is very large and has been worked for a long time.

Brandon-Italian, High Street Variety.—Though in most respects similar to the preceding, this variety is quite distinct from it in most cases. The two are closely alike in a few blocks and then cannot be

PLATE IV.



Pittsford-Italian Marble Quarry, Fowler, Vt.

Italio.—This is another of the marbles which resemble the more common varieties of imported Italian. It is a moderately light marble. The ground is bluish white, over which there are much darker bluish cloudings and shading, as if in a semi-fluid mass of lighter shade a considerable amount of darker material had been mixed. There are also not very distinct, very sinuous dark lines. Quarried at the Columbian quarry, Proctor. Until recently by the Columbian Marble Company, now by the Vermont Marble Company.

Light Cloud Rutland.—This is, as would be inferred from the name, much like Best Light Cloud, but it is a different trade variety. In this the green veins are more distinct and on this account the general tone is somewhat darker. However, the difference between the two is not great. Quarried at West Rutland by the Vermont Marble Company.

Light Columbian Building.—This is another of the very light marbles. Like several of these lightest varieties, it appears white on hammered or sawed surfaces, the marking what there may be, becoming manifest only when the stone is polished. When this variety is finished in this way, indistinct blotches and irregular bluish veins appear. Indeed, usually, there is a decided though faint bluish tone over the whole, so that the stone is never pure white. Quarried at the Columbian quarry, Proctor, by the Columbian Marble Company, formerly, now leased by Vermont Marble Company.

Light Florence.—This is also like some of the light Italian marbles. The ground is not a clear white, but has a bluish cast. It is thickly clouded and blotched by elongated dark spots and also by distinct lines. The markings are more regular than those of many of these marbles and often form somewhat uneven, but plainly seen, bands or lines across or lengthwise the piece as it is sawed across or along the block. Quarried at Fowler by the Rutland-Florence Marble Company.

Light Green Cloud.—This is one of the Dorset marbles. The ground is a very clear, sparkling white. Through this there are scattered little clouds or patches of a greenish shade. Some are quite dark and are therefore distinct, others are lighter and so indistinct that they appear more like shadows than areas of any color. Naturally these shaded areas vary greatly in different pieces. In some the dark spaces cover more of the surface than the light, while elsewhere the light predominates. It is a good building marble, but is used especially in interiors. The Slater Building, Worcester, Mass., is finished in some parts of its interior with this marble. Quarried at Dorset by the Norcross-West Marble Company.

Light Sutherland Falls.—This is a light, but not one of the lightest marbles. Through a nearly pure white ground there are distributed numerous, quite distinct, dark bluish veins. In most specimens the light ground greatly predominates over the darker veining. In occasional samples the veins are greenish rather than bluish. This variety is quite variable in shade in different layers, some being very much darker than others. It is harder than most of the Rutland marbles. Quarried at Proctor by the Vermont Marble Company.

Listavena.—This is a peculiar marble in that the usual irregularity or sinuosity of the veining or banding is here replaced by what in effect is quite a regular arrangement of the colors. The general colors are green and white in wide bands or lines which extend across the slab, or block, often in fairly straight fashion. Or it may be that we have not so much regularly straight veins of green as those that, because they all trend in the same direction, appear to be more regular than they really are. These green or greenish lines or bands are not usually as extensive as is the light ground which is itself in bands between them, though in some samples the whole surface is shaded in greens. This variety in some respects is like the Brocadillo, but in the latter the green colors occupy more of the stone than in the Listavena. The Brocadillo is more clouded and the Listavena more banded in its coloration. The latter is generally lighter than the other. Quarried at West Rutland by the Vermont Marble Company.

Mountain White.—In the region of Danby and Dorset there seems to have been a somewhat different sort of metamorphism by which harder and more brilliantly crystalline marble was formed from the original sedimentary rocks. The crystals—all true marble has a crystalline structure—are larger and thus larger reflecting surfaces appear in the smoothed surface of the stone. For these reasons all these marbles are exceptionally good building stones. The Mountain White is, as would be expected from the name, a very light stone, sometimes pure white, sometimes veined with light, or darker, brownish coloring. Much of this marble has recently been used in the new Senate office building in Washington, including sixty large columns. Quarried at Danby by the Vermont Marble Company.

Pittsford Italian.—This may be used for interior work, but it is chiefly used as a building stone. It is a very light stone, though not

as white as some of the others. The white ground is more or less thickly veined by yellowish brown lines which are sometimes quite distinct. Quarried at Pittsford by the Rutland-Florence Marble Company.

Pittsford Valley, First Quality.—This is not unlike the light Sutherland Falls. It is a hard, light marble, not quite white but of a slightly bluish tint. This bluish white ground is mottled by more or less clearly seen blotches or spots of darker bluish color. Less common, but seen here and there, are spots of pure white. Often quite indistinct, but generally to be seen, are dark veins. This stone is quarried at Pittsford by the Vermont Marble Company.

Pittsford Valley.—This is a somewhat inferior variety of the preceding and is used almost exclusively for building. The hammered surface, such as would usually be seen in buildings, is bluish white and it shows no other color except when polished. Then, indistinct mottlings and veinings like those mentioned in the stone just described appear. From the same quarry as the preceding.

Plateau White.—This is rather a very light than a white marble. The surface of a large slab shows broad, irregular bands of creamy white, alternating or intermingled with bands and clouds of greenish shades. Through these darker areas there extend numerous veins and lines of much darker green and here and there are spots or small areas of green, but of a different shade from the rest. In most specimens of this marble the green is neither so dark nor so pervasive as to make the marble dark. Indeed, in many blocks that are not polished, but only hammered, the stone appears nearly white.

This is a very hard and durable marble. The latter quality is well shown by certain old gravestones in the Dorset cemetery. Some of these are, as the dates upon them show, over a hundred years old, and though for this time exposed to a rather rigorous climate they are uninjured. In nearly all marble quarries a large amount of stone must be removed from the top layers, because of cracks or other imperfections which render it unfit for market, but from the first this stone could be used so that the usual waste was avoided. The new Harvard Medical buildings are wholly of this marble and it has been used in other fine buildings. Quarried at Dorset by the Norcross-West Marble Company.

Riverside.—This is a light, pearl-white variety with bluish veining. It is a fine, even grained marble and takes carving finely. In general appearance it is not unlike the Light Sutherland Falls, but for many purposes it is a better marble. Quarried in Proctor by the Vermont Marble Company. The quarry from which this marble is taken is near the Rutland border. It is like the Plateau quarry noticed above, in that it furnished sound and salable marble from the start.

How it may be in the Plateau quarry I am not able to say as I have not examined the surroundings of that place, but in this case there is a very possible reason for the sound condition of the stone. Mr. Norton, with whom I examined the Riverside quarry, called my attention to the very unusual glaciation of the surface. Not only was this planed off and striated, as is commonly the case with most of our ledges when freshly exposed by removal of the soil which has long covered them, but in this quarry the surface has been gouged out in deep and wide furrows, or undulations. These are several feet wide and from one to two feet deep. "Pot Holes," probably what the Swiss call "Glacier Mills," that is pot holes made by the streams from the melting of the underside of a glacier, were also found, one ten feet wide at the top and about the same in depth. At the north end there was fifteen feet of surface soil, fine sand and gravel. At the south end the top soil is not more than three feet deep. It occurs to me that the soundness of the stone at the top is because the ice carried off all the unsound, cracked layers that may have been there and that are commonly on the surface of a mass of even good marble.

Rutland Building.—Like most building marbles, this is very light. There are two recognized varieties which differ but little. A is light and more free from veins than B. Both appear nearly or quite white on the hammered surface. The veining when evident is never very marked. Quarried at West Rutland by the Vermont Marble Company.

Statuary.—The name perhaps describes this marble sufficiently, for everyone knows that the finest grained, whitest of the marbles are sought by the sculptor. No other marble commands nearly so high a price as this. Like most choice articles it is nowhere abundant. It occurs in small quantities in several of the light quarries, especially at West Rutland. It is quarried by the Vermont Marble Company.

Second Statuary.—As the name indicates, this is a Statuary, but having some imperfection cannot be sold as the best. It may be just as good in quality, but if it has even faint veining or other coloration it must take second place. It occurs with the Statuary. It is mainly quarried at West Rutland by the Vermont Marble Company.

White Rutland Building.—This while usually considered a building marble is good enough to be used as interior finish. It is a very white marble and is another of those varieties, of which there are several, which are practically pure white in the rough or hammered, and only show any veining when polished. Quarried at the Eastman quarry, West Rutland. Sold by the Vermont Marble Company.

DARK MARBLES.

These are mostly marbles in which there is a predominance of black or dark green or blue over lighter shades or white. These latter may be present and often are, but the general tone of the stone is that of the darker shades. On this account these marbles are not so commonly used as building stones as the lighter varieties, though they are sometimes and very effectively, especially when rock faced, used for the outside of buildings.

Nor are they so popular for monuments, though here again some varieties have been quite extensively sold. As it seems to me, the most fitting place for the darker marbles is as interior finish, paneling, wainscoting, floor tiling and the like. In such places many of them are much richer and more satisfactory to many at least than the lighter and therefore colder toned marbles. In some of the varieties the mixture of shades and complicated style of what may be called the pattern, are such that any verbal description must fall far short of conveying a clear idea of the real stone.

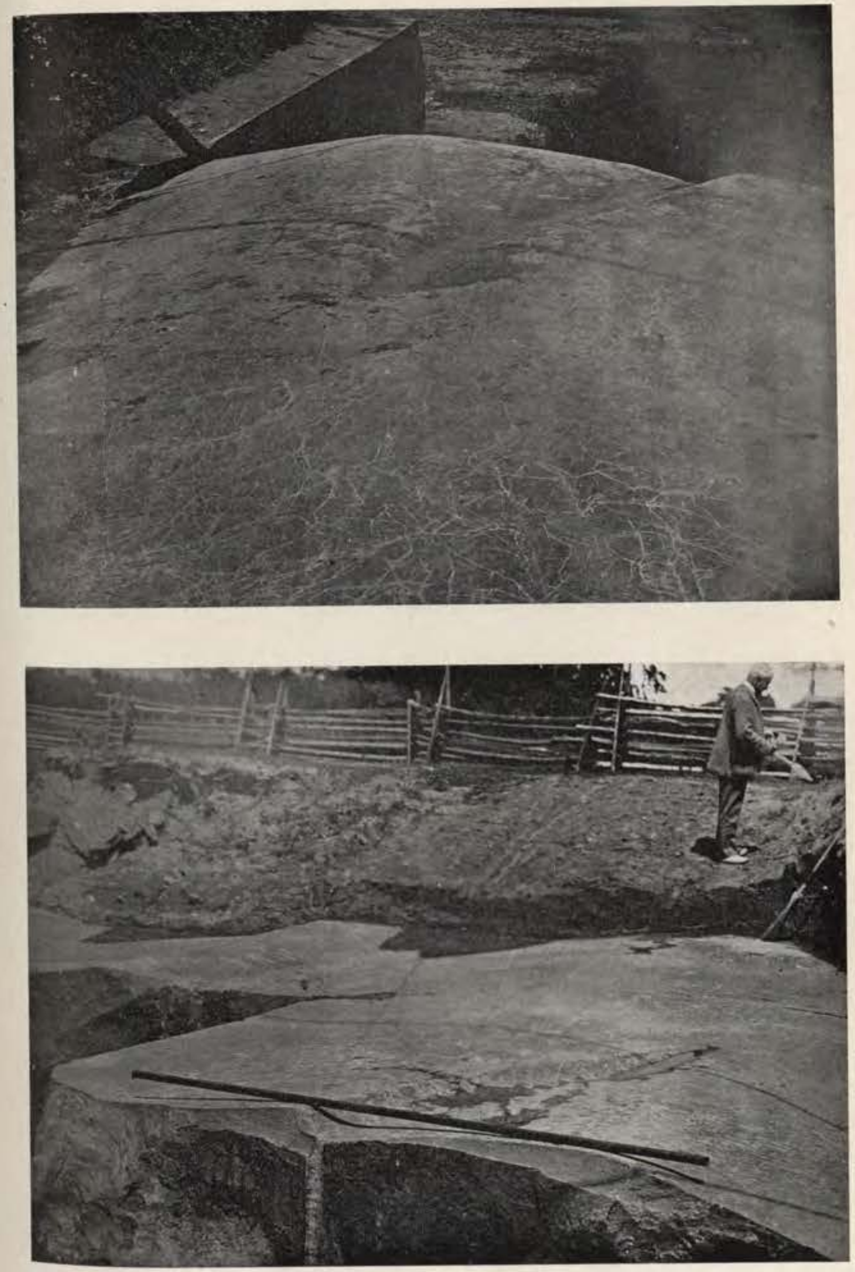
This is not the case with the entirely black sorts, for, of course, the description of these is simple because of the fact that there is not much to say, except that they are black. At different times for many years black marble has been quarried in this state. It has been obtained from several localities and in all cases is not a true marble, that is, it is not in any way changed from its original condition as limestone, and more than once from the same quarry a part of the stone has been sold to be sawed and polished, when it was black marble, a part to go into the lime kiln to come out white lime. The Rutland and Dorset marbles are all metamorphic, originally limestone of probably dark color, brown, gray or nearly black, but by processes which have been described in previous Reports they have been made over into something quite different; more, however, in appearance than in chemical constitution. Any very dark limestone of compact texture will usually when smoothed and polished give a black, or nearly black, surface. So far as I know the only limestone in this state which is sold for "marble," and for all practical purposes it is marble, is obtained at the old Fisk quarry on Isle La Motte. Beginning, then, our discussion of dark marbles with this darkest of all, we have:

Black or Fisk Black.—This is quarried, as has been stated, and is shipped in blocks to marble mills to be sawed and finished. In the quarry it is a heavily bedded, very dark, chazy limestone. Some of the stone from this quarry is lighter and when finished is dark gray rather than black, and at times has been sold as "Fisk Gray," but so far as I know, this is not kept in stock, though it could probably be obtained at any time. The best layers of the Fisk quarry finish as a fine grained, jet black stone, which is used in connection with lighter marbles in floor tiling or in various kinds of interior finish. It is for the most part finished and sold by the Barney Marble Company, Swanton.

During the summer of 1908 a large area of surface soil was cleared off from the rock, as preparation for further quarrying, and thus some very unusual glaciation was revealed. It may be noticed that this quarry, which is probably the oldest in the state, is not a deep quarry, but the stone for more than a century has been removed from a floor not much lower than the land between it and the lake, and somewhere about seven acres of rock have been quarried away. Above the nearly level beds of stone there is only the soil, which is evidently the remnant of an old sea beach, since in places it is filled with fragments of *Macoma, Saxicava* and perhaps other shells. Everywhere whenever this covering soil has been removed the surface of the underlying limestone has appeared smooth and covered by glacial striæ. The new surface differs from that heretofore exposed in that it is not merely smoothed and striated, but deeply gouged, so that it presents several deep and wide undulations. These may be seen in Plate VI, though it is not possible to show them in an illustration as strongly marked as they actually are.

At other places along the northern border of this quarry, the edge of the limestone, as seen under the earth at the top of the wall left in quarrying, is strongly undulating, so that it is plain that for some reason the glaciation of this part of the ledge was much greater than elsewhere. The area shown in the plate was much larger before a part was quarried away, as was the case when I saw it. When the photograph from which the plate was made was taken, there were

PLATE VI.



Surface of Ledge, Fisk Quarry, showing Glaciation about four hundred and fifty square feet of surface left intact. This Governor Fisk very kindly had cleaned from what dust and earth was washed or blown upon it and everything was arranged to afford the best opportunity for examining the glaciation.

The striæ were mostly not very deep, but numerous and nearly all in a north and south direction. From this there were sundry deviations, but in general the trend was as stated. Added interest was given by the numerous and very distinct sections of *Maclurea magna*, a few masses of *Stromatocerium* and other typical Chazy fossils. In general character this glaciation resembles that previously mentioned at the Riverside quarry near Rutland. The rounded ridges and grooves, each several feet across, are of the same outline. The Isle La Motte grooves are not as deep as those at Proctor, but the difference is not great. Unfortunately, the marble had been largely quarried away from the surface of the Proctor quarry before my attention was called to it, and I am not able to describe its original appearance, as has been possible in that of the Fisk quarry area. In this latter the grooves, a foot and a half to two feet wide and six to eight inches deep, the ridges having corresponding dimension, are quite regular in form, as the plate shows, and the surface is so smooth that its sheen is clearly seen in proper light.

These two examples of glacial work are especially remarkable, because of the fact that such phenomena do not ordinarily occur in Vermont. It need hardly be said that we have here abundant glaciation, but it is almost always such that the surface of the rock over which the ice moved was left smooth and flat or only gently rounded. I have never known of anything in this state at all equal to the two instances which have been given.

After this excursion we may return to our study of the marbles.

Dark Florence.—This is really about as much a light as a dark marble, and therefore might be classed with either group. On the whole, I have placed it here. It is, as the name indicates, like the Florence, except in the shade of its colors. The bluish ground is very abundantly veined by regular and fairly straight lines or bands, which are often confluent. These are dark blue. Quarried at Fowler by the Rutland-Florence Company.

Dark Vein Esperanza.—This is one of the very dark marbles. The general ground is bluish or bluish gray. Through this there are numerous veins of still darker, bluish or blackish shades which form a sort of open network and render the tone of the stone very dark.

There are also more or less abundant small white spots or blotches. In some specimens these white spots are quite numerous, but generally the veins greatly predominate. In a well-lighted location this marble presents a very rich appearance. Quarried at West Rutland by the Vermont Marble Company.

Dark Vein True Blue.—All of the Rutland dark marbles have something of a bluish cast, as some of the names indicate. There is a general resemblance between these dark varieties, but usually one familiar with them has little difficulty in distinguishing them. In this variety the ground is dark bluish or blackish, through which are numerous darker and some lighter veinings and cloudings. There are also small white areas or spots, but the dark shades greatly predominate. Quarried at West Rutland by the Rutland-Florence Company.

Extra Dark Mottled True Blue.—Another of the dark blue marbles. On a ground of very dark or blackish blue there are wavy bands and lines of lighter shade, or even white. There are also small white spots scattered through the whole, yet these are not large or prominent enough to change the dark tone of the stone. Although too dark for many locations, when properly placed this is an elegant marble. Quarried by the Rutland-Florence Company.

Extra Dark Royal Blue.—This is said to be the darkest marble found in the Rutland marble area. It is certainly very dark, but as to which of several of these dark varieties is darkest on the whole it is not easy to decide. In this the ground is a grayish blue and the darker veins or markings which run through this are very irregular and broken, so that they do not as in many sorts run on for several inches, but they are greatly broken up and present a moss-like effect. For many purposes this is a very handsome marble. Quarried by the Raleigh Marble Company at Pittsford.

Extra Dark Vein True Blue.—One of the darkest marbles quarried by the Rutland-Florence Company. The ground is dark bluish or grayish blue, over which are scattered rather abundantly not very conspicuous white spots or, less commonly, veins or blotches. Crossing the whole are many very dark veins, some of which are almost black. These very dark veins are often more or less confluent, and where they are so the marble is almost black. There is a general similarity between all the so-called "Blue" marbles, and the differences are more readily noticed in the polished stone than described in words. The ground is much the same in all, but the number and shading of the veins is not the same nor is the size and number of the light spots. The Extra Dark True Blue differs from the Dark in that the veins are more nearly black and more numerous and more conspicuous. Like the other blue marbles sold by the Rutland-Florence Company, this is quarried in West Rutland.

Florentine Blue.—A light blue marble having a much lighter ground than any of the dark marbles described thus far. Mixed in this ground are numerous, usually fine, darker blue veins. These dark veins are not very distinct and besides these there are numerous small white spots. The whole tone of the stone is a rather dark dove color. Quarried at Fowler by the Rutland-Florence Company.

Highland Blue.—A dark blue marble, though it varies in shade considerably in different specimens. Some blocks, but not all, are splashed very prettily by small white patches. These may be very irregularly strewn about or they may be arranged in some sort of lines or bands or groups. There are also light veins. In this there is a striking difference in polished and hammered surfaces, as the latter are very much lighter. Hence there is strong contrast between any carving or lettering and the polished surface on which it may be placed. Quarried by the Brandon-Italian Company at Pittsford.

Livido.—This is of medium shade, neither very light nor very dark. The general tone is that of the ground, a bluish gray through which run darker and very sinuous veins, which here and there coalesce to form dark areas. Small white spots are also scattered among the darker veins. In places the veins form tangled or confused masses which add to the dark shade of the marble. Quarried at West Rutland by the Vermont Marble Company.

ORNAMENTAL OF FANCY MARBLES.

All of the marbles included under this head might well be placed in one or the other of the previously named divisions, and it is equally true that some of those might find appropriate place here, and it is to be remembered that the three groups that have been used in this chapter are merely for convenience; no one need pay any attention to them if he prefers to ignore them.

Those varieties that are used mainly, and many of them are wholly used, for interior decoration,—or at any rate not for building nor monumental work, unless in rare cases,—are placed in this group. While commercially of much less importance than the light and dark varieties mentioned, especially the former, yet it seems to me that no Vermonter can look at a collection of these often superbly tinted and charmingly shaded marbles without a very justifiable pride in the production of his state.

Moreover, I think that very few of our people have any idea of the beauty of these marbles, and some may not even know that the state produces such varieties. It is perhaps unfortunate that for purposes of trade foreign names, imitating those of foreign marbles, have been given to so many of our Vermont varieties. Personally I should greatly prefer good, straight Yankee names for Vermont products. Many more of these fancy varieties have been quarried and sold than are named in this chapter, but those now most easily obtained are mentioned.

Æolian.—A variety which has distinctly an individuality of its own. It is in coloring similar to the Dark Green Vein, but the materials which make up the stone are arranged quite differently, so that the appearance of the polished surface is very unlike the other varieties. The ground is white and through this there are seen running in every direction green bands, veins or lines, often very wavy and more or less confluent. In some portions of the surface there is a very pretty moss-like effect. The most unique feature of the Æolian is seen in the many directions in which the colored markings extend. In most marbles there is one general direction to which all, or at any rate, most of the veins, etc., conform, but not so in this. In shade the green varies from very dark to light and there are olive shades, and now and then blotches or spots occur. The white usually has a yellowish tinge and there may be spaces of the size of one's hand without any veining and elsewhere similar spaces of green. Altogether this is a very striking and elegant marble. Examples of this may be seen in the Massachusetts Mutual Life Insurance Building at Springfield, Mass. Quarried at Dorset by the Norcross-West Company.

American Pavonazzo.—An exquisitely shaded marble and of striking appearance. On a charmingly tinted, creamy ground are scattered dark green veins. Naturally these form a very noticeable contrast with the light mass in which they are imbedded. They may be very numerous or quite sparsely distributed. They are always very wavy, irregular and often confluent, even at times blending in a dark cloud. The green of these veins is of different shades, though always dark and sometimes even black, or apparently so. This marble is quite unlike any other American stone which I have seen, except the Yellow Pavonazzo, which is mentioned later. Quarried by the Vermont Marble Company at West Rutland.

American Yellow Pavonazzo.—It is difficult to choose between so many very beautiful and really fascinating varieties, and decide which on the whole is most desirable. And perhaps no two persons would quite agree as to this, but judging simply for myself, this is at any rate one of the few most charmingly exquisite of our Vermont marbles. It is not as finely shaded as some varieties, nor is it so conspicuously elegant, but it is exceedingly charming in its general effect.

The chief color, that of the ground, is a light salmon which in some lights is more yellow or creamy, and scattered over the polished surface there are wide spaces of this color, it may be finely shaded, thus giving added charm to the whole. Somewhat irregularly and not abundantly distributed there are narrow areas or clouded spaces of dark green which forms a singularly effective contrast with the salmon shaded ground. Though so very distinct, this contrast of colors does not appear crude nor harsh, but exceedingly effective. This is especially true when it is seen in large panels or slabs, for as it is so seen it is most strikingly handsome. Like other of the peculiarly tinted marbles, this grows deeper in shade as the lower layers of the quarry are reached. Quarried at West Rutland by the Vermont Marble Company.

Columbian Listavena.—In this marble there is a yellow ground of a light shade, often almost cream color. This yellow ground is abundantly veined by moderately distinct, grayish, light brown or light olive, very undulating lines or pencilings. The effect is very pleasing and the stone quite closely resembles in appearance some of the highly valued European alabasters. Originally quarried for the Columbian Company at the Eastman quarry, West Rutland. Now controlled by the Vermont Marble Company.

There is a group often collectively called "Champlain" marbles. Geologically, they are from the Lower Cambrian Red Sandrock beds. They differ very much from the Rutland marbles in that they are not metamorphic but, except to a slight extent, are unchanged sedimentary deposits. That is, they come from an unusually calcareous portion of the Red Sandrock and each grades into the other.

The relation of these beds to others and their character has been discussed in former Reports and will be taken up in the chapter in this volume on the Geology of Chittenden County. These marbles occur at St. Albans, Colchester, Burlington and in one or two other localities, but at present they are quarried only at Swanton by the Barney Marble Company, except one variety noticed later.

All of these marbles contain a large percentage of silica and also considerable iron. They are all red marbles, that is, the predominant colors are shades of red and white. And the white is in some examples in shades, since there is the clear lusterless or dead white of calcite and the more glassy and transparent white of quartz, the former being far more abundant. Being harder than true marble, they are capable of a far more brilliant and more durable polish. For the same reason they are more costly, since sawing, smoothing and polishing are more expensive. They may be seen in many public and other buildings all over the country.

Jasper.—As has just been stated, the colors in these Champlain marbles of which Jasper is a good example are red and white. In this variety the ground is lighter than in most, being a pinkish red in which, as in a paste or soft mass, there are imbedded pieces of light red, flesh color, or white material. These pieces which make the stone a breccia, are usually angular, of every conceivable shape and, within limits, size. None are very large, at most a very few inches in longest dimension, and usually not more than one or two inches or a fraction of an inch. These light masses are generally calcite, but occasionally they are quartz. Quarried at Swanton by the Barney Marble Company.

Lyonnaise.—Another of the Champlain marbles and like the preceding is unlike any other marble sold either here or in Europe. It is a darker marble than the Jasper, and although the brecciated character of that marble also appears in this, it is much less common and does not form so conspicuous a feature of the stone. The various parts which make up the marble appear to have been more thoroughly mixed in Lyonnaise than in Jasper. The most convenient distinction, however, is in the color of the ground. In the Jasper this is pink or pinkish, while in Lyonnaise it is a deep red. There is also usually less white in the latter. The ground is sometimes almost a red-brown or chocolate. Quarried at Swanton by the Barney Company.

Moss Vein.—This is one of the Rutland marbles. It is in effect a dark variety and a very peculiar one. The ground is light, but it is nearly covered by a profusion of broad, wavy, dark veins and bands between which are light and dark areas. Some of the veins are almost black, others lighter. In all examples the surface is very dark and in some almost black. Occasionally, however, the light spaces are more numerous and of course make the whole much lighter. In many pieces the appearance is very remarkable and very handsome. Quarried at the Columbian quarry, Proctor, now controlled by the Vermont Marble Company.

Olive.—Another of the Champlain marbles. It is quite distinct in appearance from the other varieties in that, as the name indicates, another color is introduced which changes the tone of the stone. In this the ground, instead of being red as in other varieties, is drab, or olive with a drab shading. In different pieces the proportion of the olive and other, red and white, shades varies greatly and of course there is a corresponding variety in the marble. Aside from this olive there are dull grayish, red, clear white, light red shades in varying proportions. Quarried at Swanton by the Barney Marble Company.

Olivo.—This is one of the Rutland marbles. The light ground is thickly occupied by veins, bands and cloudings of moderately dark green. These shades are much like those of Brocadillo, but the arrangement is wholly different. Usually the colors are not so much in bands or lines as in less definitely marked or clouded masses. The green is yellowish or olive and of different shades. The greens and the white of the ground are about equal in extent in most specimens. Quarried at West Rutland by the Vermont Marble Company.

Oriental.—A very rich and elegant marble, one of the Champlain varieties. It is quite impossible to describe it very clearly. The brecciated appearance of much of the Champlain marble is not seen in this, but instead a very confused mixing of very singular colors, intermingled in most intricate fashion. There are many shades of dark red, there are irregular spaces of pure white and there are spaces or bands or blotches of a most unique bluish purple or lavender. Although the shades are largely dark the tone of the whole is bright and exceedingly attractive. The name is an excellent one, for the effect readily impresses one as decidedly oriental in its superbly soft, deep and yet distinct shading of the dark coloring. Quarried at Swanton by the Barney Marble Company.

Pink Listavena.—A most daintily tinted and delicately shaded stone. The ground is a light pink somewhat suggestive of salmon, though less so than that of some other varieties. This pretty ground is veined by numerous and distinct green or greenish lines and veins. Sometimes these are narrow and even become only fine pencilings. They are generally very wavy or otherwise irregular, but occasionally they are straighter and more parallel. The appearance of this marble is quite its own and does not lack character. Quarried at West Rutland by the Vermont Marble Company.

Rosaro.—This is a charmingly tinted marble and at a little distance resembles very exactly some of the varieties of the oriental alabaster, so highly valued in Europe for the most costly interior work. While quite as beautiful as alabaster, it is, of course, much harder and less liable on that account to injury. Therefore I do not see why for the same use it should not be more valuable. This would also apply with equal force to several other of our Vermont marbles. The general shade of Rosaro is a light yellow with a pink or salmon tone. The veining is so delicate that the color seems uniform at a little distance, but upon closer inspection numerous delicate, softly indistinct veins of a light olive are seen. Some of these are much more clearly defined than others but they are never conspicuous. This exquisite variety is quarried at the Eastman quarry, West Rutland, and is now sold by the Vermont Marble Company. Until lately it was controlled by the Columbian Company.

Royal Red.—One of the Champlain marbles. It is truly a royal marble. It has all the splendid coloring of the richest Numidian though differing in shade, and is harder and takes a more brilliant polish. Indeed few agates present a more glossy surface than the best of these Champlain marbles when properly finished. In this marble the ground is a deep indian red of different shades, most richly blended and in some specimens there is a sort of mottling seen. There is no other color in the stone. There are, therefore, no contrasts and the stone is elegantly simple in coloring, though there is considerable variety in the shades. All are, however, dark. Quarried at Swanton by the Barney Marble Company.

Rubio.—Another very unique marble and a very daintily tinted one. The ground is a delicate pink, inclining to salmon and this is the dominating shade of the marble. This pretty ground is very delightfully veined by softly shaded, nowhere very distinct, wavy or sinuous markings of light green. In some parts of the stone these greenish veins are closely set and a faint shading of the same green tint is spread over the intervening space as if the stone was suffused by a suggestion, rather than a clear shade, of this color. In some of the varieties we have been considering there is great and striking attraction in the distinctness of the various colors and veining, but none possess such charm, none are so peculiar to this region, so unlike other marbles, as those in which there is a blending and interclouding of the shades—shades rather than colors.

It is not necessary to notice that all this must be a matter of taste, and different buyers will inevitably choose quite different marbles, and this is well for the dealers. The location also must determine greatly the kind and color of marble used. Distinctness of shade and pattern may be most desirable in one place and indefiniteness and gentle blending of tints and shades may be far more fitting elsewhere. It is rather remarkable that to satisfy almost any conceivable taste in this respect one need not go outside of the very limited area of this state. More than this, a very large proportion of the varieties which are here mentioned are found in Rutland County. The same quarry may and often does furnish in different layers or parts of its area several quite different varieties. The Rubio is quarried at West Rutland by the Vermont Marble Company.

Ruvaro.—Although not usually so considered, and from a different locality, this marble is one of the Champlain group. That is, it is from a calcareous bed of the Red Sandrock. It only remotely resembles the Swanton marbles, though close kin to them. It is lighter than any of these and seems to have been formed under somewhat different conditions. The colors are light red and white, so mingled that there are no large areas of either. It is a very pretty and very distinct variety. Like all the Cambrian marbles it is hard and takes a brilliant polish. It is quarried at Monkton by the Vermont Marble Company.

Verde Antique.—It need hardly be noticed that, like some of the other varieties, this is a "marble" only in trade. It is a serpentine, not a limestone at all, but this does not matter. It is, like the rest, worked and sold as a marble and is used as such, so that practically it is marble though mineralogically quite different. It is a superb stone, call it what one will, and is coming more and more into favor. As the name indicates it is a green stone—green in many shades, from quite light, almost apple green, to so dark as to appear black. With these shades of green there are numerous white veins which are sometimes confluent in patches. In most specimens by far the greater part of the stone is dark green, and rarely does the white occupy more than a fraction of the mass. The shadings and veins are intricately commingled. So far as I have seen, no finer Verde Antique has anywhere been found. I have certainly seen none better, rarely so good, in European churches. It is quarried at Roxbury by the Barney Marble Company.

Verdoso.—One of the green shaded Rutland marbles. The same shades are found in Listavena, Brocadillo, Olivo and Verdoso, but there is an easily recognized difference between them, mainly because of difference in the arrangement of the colored portions, veins, clouds, etc. They differ also in the shade of green which most completely characterizes the stone. Verdoso is darker and more decidedly green than the others. In all there is more or less white through which the green colorings are distributed, but in Verdoso the white is, at least in many specimens, reduced to a small amount which does not greatly affect the tone of the stone. The green veins, or bands, or whatever, are of different shades, as is usually true in all marbles. Some are almost black, some lighter, but none very light. Quarried at West Rutland by the Vermont Marble Company.

Verdura.—A green marble somewhat similar to the preceding. The greens are usually lighter, a sort of pistachio being common. The shade varies greatly in different parts of the slab. In some places it is so light that it is greenish white rather than green, while elsewhere it is distinct and, it may be, rather dark green. The appearance suggests a mass of light green into which substances of darker green shades had been thoroughly stirred. In this variety, though the green veins are decided in color, they are not obtrusive and the effect is softened by a mottling of light olive. This is one of the marbles in which the direction in which a block is sawed, with or across, the grain, makes very great difference. Quarried at the Eastman quarry, West Rutland, now controlled by the Vermont Marble Company.

GRANITE.

The importance and almost phenomenally rapid growth of the granite industry in this state, as well as a somewhat detailed account of the principal localities in which granite is quarried, have been

discussed in previous Reports, especially the last two, and need not be taken up here.

All Vermonters are well acquainted with the general development of this industry, though it is probably true that few outside of those places in which the business is carried on are aware of the great and increasing importance of this business to Vermont. It is no small matter that a state as small in area as is Vermont should lead, not only this country, but the world, in the production and sale of two such important materials as marble and granite.

As has been shown in the discussion of marble, Vermont is not only exceptionally favored in the greatness of its marble deposits, but also in the very unusual variety which these beds afford. Granite does not anywhere occur in such diversity of color and pattern as does marble and, therefore, much greater uniformity in the granite quarried at different localities is to be expected. We have not all known varieties in this state, notably there is no red granite, though there are several localities that produce a pinkish stone that is unlike the gray varieties. Still, there are several shades of gray from quite dark to medium in Barre and Woodbury and the remarkably white granite at Bethel. The constantly and largely increasing demand from all parts of the country for Vermont granite is sufficient proof that it has no superior in quality.

Some of the large companies report that the demand for Vermont granite for building did not lessen during the financial stringency, but has been maintained without check during the past few years. Granite used in the construction, wholly or in part, of four state capitol buildings has been furnished by the Woodbury Granite Company alone during the past few years, and they are now filling that for the Wisconsin building, which calls for 600,000 cubic feet at a price exceeding $2,500,000. The others are the Pennsylvania, Kentucky and a portion of the Iowa, capitols.

As heretofore, it is difficult to obtain accurate and complete statements as to the extent of the granite business in Vermont. Many firms engaged in this industry do not respond to inquiries as to their business, and the sum total is more or less affected by this. For the year 1906 the United States Geological Survey publications state the amount of building and monumental granite produced in Vermont as $2,920,373. To this should be added the large amount sold in the rough and the much smaller amount sold as crushed stone. So far as I can ascertain the total amount is not less than $4,000,000 and probably considerably more. Something of the extent of the business can be gained from the following facts respecting Barre, taken from Rock Products:

"The Barre granite industry in Barre alone employs sixteen hundred granite cutters at $3.00 a day, one hundred and fifty tool sharpeners at $3.00, one hundred polishers at $3.00, two hundred bumpers at $2.25, thirty engineers at $2.50 and seventy-five grinders at $1.00, making a daily pay-roll of $6,150. For three hundred days in the year the pay-roll is $1,845,000. On the quarries are employed one thousand men at an average rate of $2.00, making an annual pay-roll on the hill of $600,000, the total of both quarry and shed employés' pay-roll amounting to $2,445,000. This does not include salaries of superintendents, foremen, apprentices, bookkeepers, stenographers, etc., which would certainly swell the total to considerably more than two and one-half millions a year. There is no accurate method of determining just how much work was shipped from Barre during the past year, but by figuring a reasonable percentage of profit over and above about two million seven hundred thousand dollars, the amount approximately paid out in wages, wear and tear, necessary improvements, interest on investment, etc., the production can be estimated."

The granite business in Barre, Montpelier and the immediate neighborhood was tied up for six weeks in the spring of 1908 by a general strike, but as soon as a settlement was reached everything went on as before, and the total volume of business for the year will not be seriously affected. One of the local papers stated that within the first week of resumption seventy-five carloads of rough stock were shipped from the quarries, mostly to retail dealers.

From personal examination of many of the quarries in the Barre region, I can testify to the vast quantity and the excellent quality of the granite deposit. In previous Reports illustrations of a number of these quarries have been given and a general account of the location. In addition there have been given in the Reports several more technical papers on the region and the granites. In the present Report there will be found on following pages an important paper on the Granites of Vermont by Professor Dale. In many of these quarries all the conditions desirable for successful quarrying are easily met. As to size there seems to be no limit to the dimensions of pieces that can be quarried, except the ability of machinery available to handle the masses when taken out. So far as I know, the

largest piece actually gotten out is one that was quarried at one of the Wetmore and Morse quarries.

This was a sheet ninety-five feet long, forty-five feet wide and twenty-five feet thick. It was estimated that its weight was 10,687 tons and it contained 106,875 cubic feet. The quality was of the best. Of course no such mass can be taken out of the quarry, but must be cut into sizes that can be handled by derricks. The largest finished pieces that have been shipped from Barre were sent to Wheaton, Ill., by the Jones Brothers' Company early in the spring. These were roof pieces for a mausoleum. Each was thirty-five feet long, nine feet four inches wide, one foot four inches thick. Four forty-ton cars were made to transport these large pieces. Other companies have shipped similar roof pieces which were nearly as large. At Barre, Woodbury, Derby and Bethel such huge masses can be quarried, and what is of greatest importance they can be obtained without difficulty, of uniform color and texture throughout.

At Barre, as elsewhere, new methods of working the stone and new machinery are continually being adopted. On this account while the volume of business has increased steadily for the past ten years, that in 1906 being 91 per cent greater than that in 1902, yet the number of men employed has not proportionally increased, since machinery has taken the place of men in all departments of the work. Another change that has taken place is in the main motive power. Formerly only steam was used, except in those unusually fortunate companies which could use water power. Now electricity is taking the place of steam as fast as circumstances allow, and the same is true in the marble mills. The possibility of transmitting electric power through some miles of distance makes it possible to use water power as it could not otherwise be used on account of location and this possibility is affecting the stone working business of the state very materially and greatly to its advantage.

There are in and about Barre at the present time (1908) one hundred and ten companies engaged in quarrying or cutting granite. Of these ten are engaged in quarrying as well as cutting, sixteen quarry only, selling all their product as rough stock, but most of the quarrying firms have also cutting sheds. By far the larger number of the Barre and most of the Montpelier companies buy the rough stock from the quarries and own only cutting sheds. The list at the end of this section indicates these facts, and shows that in Barre there are eighty-four companies having cutting sheds only and in Montpelier there are twenty-six more. Of the Montpelier companies only three work quarries.

Frequent inquiries have come to the Geologist as to the composition, crushing strength, etc., of the Vermont granites. Not a large number of these have been made; most of our companies have relied mainly on the tests which have come in the regular use of their product. At the close of this section on granite there is given a table containing analyses of several different kinds of Vermont granite by competent chemists. The following is from a report which has been sent to this office by the Jones Brothers' Company. While the results of various tests given are those obtained by examination of granite from one firm, it is quite certain that they represent very nearly average specimens of the best Barre stone.

Results of microscopal examination by Prof. Whitman Cross, Government expert.

"Jones Brothers' Company's Dark granite is a fine, even grained typical granite, containing two micas (biotite, miscovite), sometimes called 'granite proper.' The constituents of importance are quartz, orthoclase, microcline, biotite and muscovite. The first three occur in wholly irregular grains interlocking in very complex manner. The micas are in small leaves between and penetrating the other minerals to some extent. Muscovite apparently occurs in two forms, one corresponding to the biotite as seemingly primary and in small flakes in the orthoclase and secondary mineral.

"Accessory constituents are oligoclase albite, titanite (sphene) and apatite. There is an almost total absence of magnetite or other iron ore.

"Biotite is slightly changed to green and probably yields chlorite in some samples. The orthoclase gives way to an aggregate of fine muscovite leaves also, varying much in different samples, no doubt.

"Both quartz and biotite show that the rock has endured considerable pressure, the former by the 'undulatory extinction' it exhibits and the biotite by the curved and bent lamellæ. The pressure did not extend to a crushing of the grains or any banded structure.

"In the feldspars is some calcite filling small cracks. On the basis of this examination, I should estimate it at quartz 30 to 35 per cent, orthoclase 30, microcline 20 to 25. Much of the iron is present in the fenous or unoxidised condition."

The following tests were made by Dr. Wm. C. Day of the U. S. Geological Survey.

Determinations of Specific Gravity.

DARK GRANITE.	Grams.
Weight of granite	8.8061
Weight of water displaced	3.2956
Specific gravity found	2.672
Temperature of water, 22° C.	

MEDIUM GRANITE.	Grams.
Weight of granite	32.95745
Weight of water displaced	12.37680
Specific gravity found	2.662
Temperature of water 20° C.	

Determination of Absorptive Capacity.

DARK GRANITE.	Grams.
Weight of sample after heating in air at 110° C. for six hours	49.9625
Weight of same after boiling in water for three hours and wiping dry	50.0280
Gain in weight from water absorbed	.0605
Weight after heating again at 110° C. for six hours	49.9228
Per cent of water absorbed	.121

MEDIUM GRANITE.	Grams.
Weight of sample after heating in air at 110° C. for six hours	64.1788
Weight of same after boiling in water for three hours and wiping dry	64.2549
Gain in weight	.0826
Weight after heating again at 110° C. for six hours	64.1534
Percentage of water absorbed	.129

"While the foregoing results speak plainly for themselves to the effect that the Dark and the Medium granites quarried by Jones Brothers' Company at their quarries in Barre, Vermont, are unquestionably commendable for the customary uses of granite, it may be well to call attention to certain features of these results which are worthy of special mention. The analysis shows a low percentage of iron, rendering liability to stain a minimum, a high percentage of silica, and the percentage of the other constituents such as are found in the true granites.

"The crushing strength of the Dark granite is high, much above the average for true granites, and somewhat higher on the average than that of the Medium.

"An examination of the stone at the quarries by the writer shows it to be unusually free from knots and streaks, or irregularities in structure of any kind.

"The absorptive capacities of both Dark and Medium, while showing a slight difference in favor of the Dark, are both so low as to amount virtually to nothing when possible disintegration from the freezing of absorbed moisture is considered. In this connection it must be remembered that in the absorption test the stone is so treated as to absorb the maximum quantity of water, *i. e.,* the conditions of the test are far more severe than any natural conditions to which the stone is ever likely to be exposed."

The granite belt which is so wonderfully developed at Millstone Hill and thereabouts near Barre, for all the Barre quarries are outside of the city at a distance of several miles, is continued, or at least reappears, at Calais. Here there are several quarries which are vigorously worked and produce a good and slightly different granite. Though a perfectly satisfactory granite and according to the testimony of stonecutters an exceptionally good stone for cutting, the Calais granite is not usually sold under its own name. The offices are in other places and the name Barre granite has such credit in trade that so far as I am aware most of the product of the Calais quarries is sold either without local name or as Barre. There is, so far as I can see, no reason for this, as the granite is good enough to stand on its own merits—if buyers will only think so.

Beyond Calais we come to the great deposit at Woodbury. Here there is a small mountain of granite. Heretofore it has been used more largely as a building stone than for monuments. Still some very fine mausoleums and large and costly monuments have been cut from this stock and have, so far as I can ascertain, given perfect satisfaction. Hundreds of carloads have been sent from here, first to Hardwick, where most of the cutting is done, and thence on to their final destination. The largest company doing business in this

section is the Woodbury Granite Company, owning quarries in Woodbury and very extensive works in Hardwick. This company claims to be the largest granite producing concern in the world. This is a pretty large statement, but I see no reason to doubt it, especially if to the very large works at Hardwick there are added the also extensive works at Bethel. At this latter place this company has recently built a new mill 256 x 140 feet, with more than an acre of floor space, in addition to what they have had there. All these mills and quarries are fully equipped with the most improved appliances for handling and working stone. The manager reports enough orders now in hand to occupy them fully for six years. They have received during the past year contracts for seventeen buildings, some of them large and costly.

They have about eight hundred on their pay-roll when fully occupied, and can turn out 25,000 cubic feet of finished granite per month. To the already immense plant at Hardwick improvements costing $250,000 have recently been added. Arrangements have been made by which the company controls electricity enough to carry their whole equipment in mills and quarries and probably by the time this is in print no steam power will be used either at Hardwick or Bethel.

The main quarry of this company is at Woodbury, which produces the gray granite used mostly for building, but they have recently bought the "Bashaw" quarry near this and from it are able to get a dark, fine grained granite which is becoming very popular for monuments, as is the Dark Barre which it resembles. They are now selling monuments and mausoleums of this stone at the rate of $20,000 a month. They also have a large quarry at Bethel, from which the white granite is taken.

The Woodbury gray granite is worked by Mr. E. R. Fletcher and others, as the list shows. Mr. Fletcher's quarry is in the same deposit as that of the Woodbury Granite Company and he has also a large cutting plant.

There are at Hardwick and Woodbury twenty-five companies quarrying or cutting granite, as at Barre the cutting firms are much more numerous, only seven working quarries.

The great development in the granite business at Bethel, started a very few years ago, apparently is very flourishing. As stated above, the Woodbury Granite Company has a quarry and a large cutting plant here and the E. B. Ellis Company larger quarries and very extensive works at Northfield, where all the granite cut by them is taken. The stone is almost white, very strong and unsurpassed as a building stone. For this purpose a great quantity has already been sold.

The boom, for it has amounted to that, in the Bethel granite started a few years ago when the Ellis Company secured the contract for furnishing the stone for the Union station at Washington. This great structure is entirely built of the Bethel granite and is the best example of the quality of the stone for building purposes. The Wisconsin capitol mentioned above is also to be of this stone. It can also be carved. I take the following item from Rock Products:

"Six blocks of granite for the largest statues ever cut from this material have just been taken from the E. B. Ellis quarries in Bethel under the direction of Louis St. Gaudens, brother of the famous sculptor, recently deceased. The statues, representing Agriculture, Imagination, Mechanics, Freedom, Electricity and Fire, are to surmount the central pavilion of the Union station at Washington, D. C. When completed they will weigh over forty tons each and a year will be consumed in carving them. They are the largest of the kind ever quarried in the United States. The finished statues, which are each to be cut of one piece, will stand 16 feet high. The rough blocks weigh over 80 tons each."

The above shows that it is possible to carve elaborate figures from this granite. It is, however, coarser in its grain than other granites found at Barre or Woodbury, but it has a very white surface when hammered and is probably by far the strongest granite quarried in the state.

The Newport Granite Company, with a fine quarry at Derby, near Newport, and main office at Albany, N. Y., are doing a good business in a medium shade of gray granite.

At Randolph Mr. A. H. Beedle has some very promising ledges which have been worked only for purposes of prospecting.

The deposit is about a mile from the railroad station. The stone is somewhat unlike any other that I have seen. It resembles the Bethel more closely than any other, but is finer, a little darker, and when polished presents a very handsome surface.

Another as yet undeveloped mass of granite is at Rochester. This has been worked to some extent. The granite is one of the lighter gray varieties, but quite different from other Vermont stone. There is a large mass of it and if properly developed might easily command a good market, provided transportation to the railroad could be obtained at low rates.

There has been quarried somewhat irregularly at Mt. Ascutney, Windsor, what is known to the trade as "Windsor Green Granite." Technically it is a syenite of the variety called Nordmarkite by Dr. Daly in his exhaustive bulletin on the region. In the report for 1903–4 I have quoted somewhat at length from Dr. Daly's description (Bulletin U. S. G. S., 209). The stone is a very peculiar dark, olive green syenite, which takes a fine polish and has been used for columns and interior finish in some large buildings. Perhaps the large columns which support the dome of the Library of Columbia University are as typical examples as there are. There is no stone resembling this for sale anywhere. An analysis is given in the table. There are three quarries of this stone, two on the north and one on the west side of Ascutney. The stone occurs in abundance and is in good position for getting out, but the quarries are none of them at present worked. The oldest and largest is owned by Norcross Brothers and is worked by them, I understand, from time to time as they have use for the stone. The other two are owned by the Enright estate, and were formerly worked by the Enright Granite Company. From the quarry on the west side of the mountain, which furnishes a stone of finer grain than is found elsewhere, the sarcophagus was taken in which rest the remains of President McKinley.

The Enright Company have also made a large number of small monuments from this stone. The polished surface is very much darker than when cut or hammered and for this reason any lettering or carving is much more than ordinarily distinct. The stone has exceptional attraction for those who desire so dark a material for monumental purposes. Since the death of Mr. Enright no work has been done at the quarries and probably will not be until new hands take hold of them.

A table containing analyses of several varieties of Vermont granite is given on the following page. While I regret that a larger number of such analyses are not available, it is probably true that those presented below fairly represent all the best varieties that find their way into market.

ANALYSES OF VERMONT GRANITES.

	Barre. Dark and Medium. Jones Brothers.	Woodbury. Medium. Woodbury Granite Co.	Bethel. White. Woodbury Granite Co.	Randolph. Light. A. H. Beedle.	Windsor. "Green Granite." Norcross Brothers.
Silica—SiO_2	69.56	70.75	71.80	71.80	65.43
Iron Oxides	2.65	2.70	trace	trace	65.43
Alumina—Al_2O_3	15.38	15.80	18.25	20.78	16.11
Manganese	trace	trace	trace	trace	.23
Lime—CaO	1.76	2.03	2.80	trace	1.49
Magnesia—MgO	trace	1.35	trace	trace	.45
Sodium Oxide—NaO	5.38	3.88	4.52	4.40	5.00
Potassium Oxide—KO	4.31	3.46	.95	2.99	5.97*
Loss on ignition	1.02	.35	.60	....	

*This contains very small quantities of TiO, ZrO_2, P_2O_2, Cl., F, BrO.

NOTE.— Analyses, crushing tests, etc., may be found on pp. 103-105, Fifth Report, 1906.

It must be of interest to all granite workers that the granites of Vermont have been thoroughly studied by a competent expert. During the summer of 1907 Prof. T. N. Dale spent several months in the state investigating all of the more important granite deposits, under the direction of the United States Geological Survey. For some years Professor Dale has been studying the granites of New England and it is with very great satisfaction that through the courtesy of the Director of the U. S. Geological Survey and also through that of Professor Dale an abstract of the paper giving the results of this work can be given here. The full paper is to be published later as one of the Bulletins of U. S. G. S.

The summary by Professor Dale immediately follows this chapter.

When the list of stone working companies in this state was first published in a previous Report, there was no intention of repeating it, but ever since it has been in demand, and as continual changes are taking place, especially in the granite companies, a revised list seems called for. The lists of marble, granite and slate companies published in the last Report are given in the present volume, with such corrections as have been made necessary during the past two years. As heretofore, I am especially indebted to Mr. William Barclay of Barre, also Mr. George James of Hardwick, for valuable aid in bringing the list up to date.

Those names marked Q. have only quarries, C. only cutting plants, while Q. C. indicates that the firm work both quarries and "cutting sheds." Only the larger concerns which have a considerable business are included in these lists. There are many smaller firms which only supply the local demand, chiefly for monuments.

LIST OF GRANITE COMPANIES IN VERMONT.

BARRE AND VICINITY.

Adie & Milne, Barre, C.
Anderson & Sons, Barre, Q. C.
Abbiati & Columbo, Barre, C.
Appiani & Fraquelli, C.
Barclay Brothers, Barre, Q. C.
Barclay, Andrew & Co., Barre, C.
Barney, Auguste, Websterville, Q.
Barre Blue Granite Co., Barre, Q.
Barre Granite Co., Barre, Q. C.
Barre Medium Granite Co., C.
Barre White Granite Co., Barre, Q.
Barre Granite Quarry Co., Barre, Q.
Barton Hayes & Bancroft, Barre, C.
Beck & Beck, Barre, C.
Bessey Granite Co., Barre, C.
Bianchi, Charles & Son, Barre, C.
Bilodeau, J. O. & Co., E. Barre, C.
Bond & Kidder, Barre, Q. C.
Bond & Whitcomb, Barre, Q.
Boutwell-Milne-Varnum Co., Barre, Q. C.
Bruce, A. E. & Sons, Barre, Q.
Brown, John & Co., Barre, C.
Brusa Brothers, Barre, C.
Bugbee, E. A. & Co., Barre, C.
Burke Brothers, Barre, C.
Canton Brothers, Barre, Q. C.
Carle, E. W., Barre, C.
Carroll & McNulty, Barre, C.
Carusi, E. A., Barre, C.
Chiold Brothers, Barre, C.
Coburn & Ellis, Barre, C.
Cole, W. & Sons, Barre, C.
Comolli & Co., Barre, C.
Consolidated Quarry Co., Barre, Q. C.
Corskie, J. B. & Son, Barre, C.
D. B. L. Granite Co., East Barre, C.
Densmore, C. D., East Barre, C.
Desoreau & Co., East Barre, C.
Dewey, Col. Cutting Works, Barre, C.
Dineen & Co., Barre, C.
Eclat Granite Co., Barre, C.
Excelsior Granite Co., Barre, C.
Freeman & Wasgatt, Barre, C.
Gasparello Brothers, Barre, C.
Gallagher, L. B., Barre, C.
Glysson, E., Barre, C.
Grapponi Brothers, Barre, C.
Grearson & Lane, Barre, C.
Grearson-Beckett Co., Williamstown, Q.
Guidici Brothers & Co., Barre, C.
Hall, W. A., Barre, C.
Harper, Gallagher Co., Barre, C.
Harrison Granite Co., Barre, C.
Hoyt & Lebourveau, Barre, C.
Johnson & Peterson, Barre, C.
Johnson & Gustafson, Barre, C.
Jones Brothers' Co., Barre, Q. C.
Jones, A. S., Barre, C.
LaClair & McNulty, Barre, C.
Leland Company, Barre, C.
Libersont, George, Websterville, C.
Littlejohn, Odgers & Milne, Barre, C.
McDonald & Buchan, Barre, C.
McDonnell & Sons, Barre, C.
McIver, Mattheson & Co., Barre, Q. C.
McMillan, C. & Son, Barre, C.

McMinn, J. & Sons, Barre, C.
Macchi, Z., Barre, C.
Manufacturers' Quarrying Co., Barre, Q.
Marciasi, O. N., Barre, C.
Marr & Gordon, Barre, Q.
Marrion & O'Leary, Barre, C.
Martinson, John A., Barre, C.
Melcher & Hadley, Barre, C.
Milne & Robertson, Barre, C.
Moore, Chas. H. & Co., Barre, C.
Moore Brothers, Barre, C.
Mortimer & Hadden, Barre, C.
Murray, J. F., Barre, C.
Mutch & Calder Granite Co., Barre, C.
Newcombe, T. J., Barre, C.
North Barre Granite Co., Barre, C.
Novelli & Calcagni, Barre, C.
Oliver & Co., Barre, C.
O'Herrin, Robert & Co., Websterville, C.
Parry & Jones, Barre, C.
Parnigoni Bros., Barre, C.
Phillips, Findlater & Co., Barre, C.
Pirie, J. K., Graniteville, Q.
Presbrey-Coykendall Co., Barre, C.
Provost & Boussiere, Gouldsville, Q.
Pruneau, John, Websterville, Q.
Rae, James & Son, Barre, C.
Rizzi Brothers, Barre, C.
Rizzi, L. G., Barre, C.
Robins Brothers, Barre, C.
Ross & Ralph, Barre, C.
Rosse & Cassellini, Barre, C.
Sanguinetti, A. & C., Barre, C.
Saporiti, J. P., Barre, C.
Scandia Granite Co., Barre, C.
Scott Brothers, Barre, C.
Sector, James & Co., Barre, C.
Smith, E. L. & Co., Barre, Q. C.
Smith Brothers, Barre, C.
Standard Granite Co., Barre, Q.
Star Granite Co., Barre, C.
Stephen & Gerrard, Barre, Q.
Stevens & Denning, Barre, C.
Straiton, George, Barre, C.
Sunnyside Granite Co., Barre, Q.
Sullivan, Eugene, Barre, C.
Sullivan, J. J. & Co., East Barre, C.
Thom, Clark & Co., Barre, C.
Walker, Geo. & Sons, Barre, Q. C.
Wells-Lamson Quarry Co., Barre, Q.
Wells & Barney, Websterville, C.
Woodcock Bros., Barre, C.
World Granite Co., East Barre, C.
Young Brothers, Barre, C.

MONTPELIER.

Aja Granite Co., Montpelier, C.
American Granite Co., Montpelier, C.
Bertoli, H. J., Montpelier, C.
Bianchi Granite Co., Montpelier, C.
Bonazzi & Bonazzi, Montpelier, C.
Bowers, R. C., Granite Co., Montpelier, C.
Craven, E. E. & Co., Montpelier, C.
Dillon & Haley, Montpelier, C.
Doucetti Brothers, Montpelier, C.
Fernandez, P., Montpelier, C.
Frazier, R. M., Montpelier, C.
Gill, C. P. & Co., Montpelier, C.
Gillander & Keough, Montpelier, C.
Globe Granite Co., Montpelier, C.
Hill, Felix A., Montpelier, C.
Jurras, J. & Co., Montpelier, C.
Lillie, D. K., Montpelier, C.
McCann & Maroni, Montpelier, C.
Mills & Co., Montpelier, C.
Murley, J. P., Montpelier, C.
National Granite Co., Montpelier, C.
Patch & Co., Montpelier, Quarry at Adamant.
Pioneer Granite Co., Montpelier, C.
Poulin, J. Granite Co., Montpelier, C.

Provost, S., West Berlin, C.
Ryle & McCormick Co., Montpelier, C.
Sibley, Clark, E. Montpelier, Q.
Sweeney Brothers, Montpelier, C.
Wetmore & Morse Granite Co., Montpelier, Q.

NORTHFIELD AND BETHEL.

Brusa & Giffin, Northfield, C.
Brusa, P. & Co., Northfield, C.
Cannon & Slack Co., Northfield, C.
Cross Brothers, Northfield, C.
Devine & Burns, Northfield, C.
Ellis, E. B. Granite Co., Quarry at Bethel, Cutting works at Northfield, Q. C.
Empire Granite and Quarry Co., Northfield, C.
Northfield Union Granite Co., Northfield, C.
Pelaggi, N. & C., Northfield, C.
Phillips & Slack, Northfield, C.
Woodbury Granite Co., Bethel, Q. C.

HARDWICK AND WOODBURY.

American Granite Co., Hardwick, C.
Bailey & Rollins, Hardwick, C.
Blackhall & Hay, Hardwick, C.
Calderwood & Merriam, Hardwick, C.
Crystal Brook Granite Co., Hardwick, C.
Daniell, T. T., Hardwick, C.
Donald, Wm. B., Hardwick, C.
Fletcher, E. R., Q. C.
Hardwick Granite Co., quarry at East Hardwick, C.
Hardwick Monumental Quarries Co., Quarry at Woodbury.
Hardwick Polishing Co., Hardwick, C.
Howard & Martin, Hardwick, C.
Jackson & Owens, Hardwick, C.
James Granite Co., Hardwick, C.
Mack, J. W., Hardwick, C.
Murch, E. R., Hardwick, C.
Pinera, Ramon, Hardwick, C.
Smith & Barter, Hardwick, C.
Stewart Granite Works, Hardwick, C.
Sullivan, J. E., Hardwick, C.
Timpano & Pelaggi, Hardwick, C.
Tretheway, John S., Hardwick, C.
Union Granite Co., Hardwick, C.
Vavala, Frank, Hardwick, C.
Woodbury Granite Co., Hardwick, Quarries at Woodbury and Bethel, Works at Hardwick and Bethel.
Ainsworth & Mack, Woodbury, Q.
Drenan & Brown, Woodbury, Q.
Fletcher, E. R., Woodbury, Q.
Robie, L. S., Woodbury, Q.

GROTON AND RYEGATE.

Benzie and Company, Groton, C.
Frazier, Donald, Groton, C.
Hosmer Brothers, Groton, C.
Anderson, South Ryegate, C.
Beaton, James, Ryegate, C.
Bussey Brothers, Ryegate, C.
Farquharson, R., Ryegate, C.
McDonald, M. F., Ryegate, C.
Metcalf, H. E., Ryegate, C.
Morrison, D. A. & Co., Ryegate, C.
Rabioli, J. D., Ryegate, C.
Booth, C. L., Groton, C.
Hendry and Weber, Groton, C.
Beaton, A. T., Ryegate, C.
Blue Mountain Granite Works, Ryegate, Q. C.
Craigie, James, Ryegate, C.
Grant, C. H. C., Ryegate, C.
Roben, Geo., Ryegate, C.
Rosa Brothers, Ryegate, C.
Ryegate Granite Works, Ryegate, Q. C.
Sanderson, H. C., Ryegate, C.

OTHER PARTS OF THE STATE.

Davis Brothers, West Berlin, C.
Daniels, Drew, Waterbury, C., Quarry at Calais.
O'Clair & Anair, Waterbury, C.
Calais Granite Co., Calais, Q.
Chapman, W. J., West Concord, C.
Daniels, J. C., West Concord, C.
Grout Granite Quarry, West Concord, Q.
Kearney Hill Granite Co., West Concord, Q.
Burke Granite Co., West Concord, Q.
Carlton & Lake, East St. Johnsbury.
Lyon, G. E. Granite Co., Dummerston.
Clark, James, West Dummerston.
Lake Shore Granite Quarry, Adamant, Q.
Tillcrop Granite Co., West Concord, C.
Welch, Joseph, West Concord, C.
Williamson, Harry, W. Concord, C.
Newport Granite Co., Albany, N. Y., Quarry at Derby.
Ayer, E. S., West Danville, C.
Goss, A. J., West Danville, C.
McGillie, West Danville, C.
Waldo, M. E., West Danville, C.

LIMESTONE.

Limestone has never made a very large showing in the assets of this state. Yet it is of sufficient importance to demand attention. There are a few quarries from which limestone is taken for building or road material, or, to a small extent, marble, as has already been noticed in speaking of black marble. Most of the limestone quarries in the state quarry this material in order to burn it for lime. So far as I know, the only large quarries from which the stone is taken for building, curbing, etc., are the Fisk and the Fleury quarries on the south end of Isle La Motte. There are lime kilns and adjoining quarries at Swanton, John P. Rich; Highgate, L. E. Felton; St. Albans, W. B. Fonda; Colchester, G. B. Catlin; Leicester Junction, Brandon Lime and Marble Company; Leicester, Marble-Lime Company; Amsden, Amsden Lime Company, and perhaps in a few other places. In 1906 Vermont produced lime to the value of $367,393.

SLATE.

In the Report immediately preceding this (Fifth) a somewhat extended account of the methods used in manufacturing slate was given, together with illustrations of some of the machinery employed. As shown in the section mentioned, the variety of uses to which slate is put has greatly increased during the last few years and of course this increases the demand for this material.

On the farm of Mr. E. O. Cool, a couple of miles southwest of Brandon village, there is a deposit of importance. This appears to be the extreme northern limit of the western or great slate belt of Vermont. It is from this belt, in Fairhaven, Poultney and Pawlet that nearly all the Vermont slate is taken.

At the Cool quarry there is a large deposit which has been considerably worked during the past five years, but not enough to show satisfactorily the real quality of the stone. Three openings have been made and, taking into account the fact that most of what has been obtained is near the surface, the slate is of good quality, though not like that which usually comes from deeper in the quarries. The slate here is mostly green, said to be the very desirable sort known in trade as "Unfading Green," but there is also that which is dark gray or nearly black.

This mass of slate is some miles farther north than the great western slate belt has been supposed to extend, but it is evidently a part of the large mass which reaches from north to south for not far from thirty miles.

During the year 1907 there was a strike which extended through the slate belt and for a time seriously crippled the business. Most of the slate manufacturers obtained other help after a short time and went on with their works; but not only during the nine months of the strike, though necessarily then to an especial degree, but since it closed, the whole slate business has suffered from a depression from which it has not recovered. Nor does it seem likely that it will for a long time, if ever, since, during the inability of the mills to furnish their orders or to accept new ones, business that would have come to Vermont went to Pennsylvania where it remains. This strike seems to have been wholly uncalled for, as the workmen were not in any way dissatisfied and had no demands to make of the companies. The companies did not recognize the union and would not agree to employ only union men, hence the national officers ordered the strike which, so far as can be ascertained, has resulted in great injury to many and good to none. In addition to the effects just mentioned, the general business depression has also had its effect. Many of the mills are only partly at work, others are closed.

The above refers particularly to what is known as mill work, that is, manufactured slate, billiard table tops, switch boards, stair treads, etc. The roofing slate business has not suffered nearly as much. One of the most prominent proprietors of slate quarries writes as follows: "The Sea Green business has never been better than this year, the demand being very strong all the year and it has been a hard problem for the manufacturers to fill all the orders they have received. Prices are good. The Unfading business is improving every day, not only the demand, but the production is increasing."

LIST OF VERMONT SLATE COMPANIES.

CASTLETON.

Criterion Slate Company, Hydeville.
Hayes Slate Company, Hydeville.
Hinchey Brothers, Hydeville.
Hydeville Slate Works, Hydeville.
John J. Jones Slate Company, Castleton.
Minogue Brothers and Quinn, Hydeville.
Metalo Slate Company, Hydeville.
Minogue, James, Castleton.
Penryn Slate Company, Hydeville.
Union Slate Company, Hydeville.

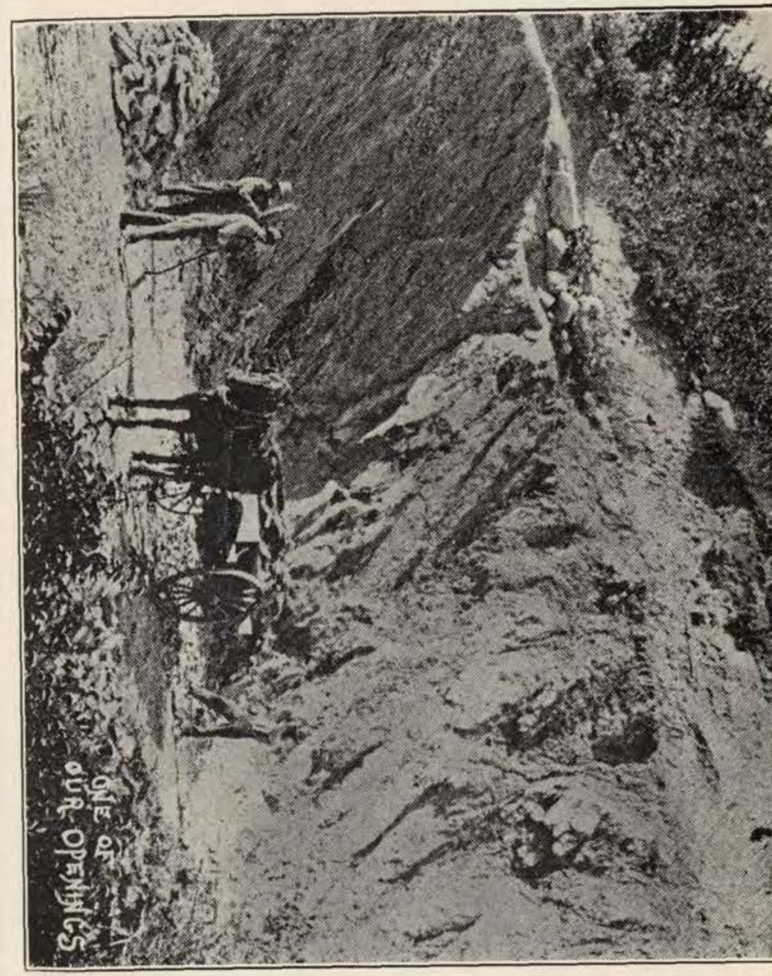
FAIRHAVEN.

Allens, S. Sons, Fairhaven.
Bonville Brothers, Fairhaven.
Bonville, E., Fairhaven.
Coleman and Westcott, Fairhaven.
Durick and Connors, Fairhaven.
Durick and Flannagan, Fairhaven.
Durick and Keenan, Fairhaven.
Durick, Keenan and Flannagan, Fairhaven.
Fairhaven Marbleized Slate Company, Fairhaven.
Jones and Owens, Fairhaven.
Jones and Francis, Fairhaven.
Maley Brothers, Fairhaven.
McNamara Brothers, Fairhaven.
Mahar Brothers, Fairhaven.
Peerless Slate Quarry, Fairhaven.
Pelkey Brothers, Fairhaven.
Valley Slate Company, Fairhaven.
Vermont Marbleized Slate Company, Fairhaven.
Vermont Unfading Green Slate Company, Fairhaven.
Victor Slate Company, Fairhaven.
Young, A. B., Fairhaven.

POULTNEY.

Auld and Conger, Poultney.
Eastern Slate Company, Poultney.
Edwards Slate Company, Poultney and Wells.
Eureka Slate Co., North Poultney.
Green Mountain Slate Co., Poultney.
Griffith and Nathanael, Poultney.
Hughes-Snyder Slate Co., Poultney.
Jones, Roberts and Rowland, Poultney.
Martin, Mrs. Isabel, Poultney.
Matthews Slate Company, Poultney.
Morris, Charles, Slate Co., Poultney.
New York Consolidated Slate Company, Poultney.
Rice Brothers, South Poultney.
Rutland County Slate Co., Poultney.

PLATE VII.



Clay Pit, Rutland Fire Clay Company.

PAWLET AND WELLS.

Layden and Burdick, West Pawlet.
Hughes, W. H. Slate Company, West Pawlet.
Nelson Bros. and Morow, West Pawlet.
O'Brien Brothers, Wells.
Rising and Nelson, West Pawlet.
Roberts, G. T., West Pawlet.

GRANVILLE, NEW YORK, QUARRIES IN VERMONT.

Norton Brothers, Granville, N. Y.
Sheldon, F. C., Granville, N. Y.
Vermont Slate Co., Granville, N. Y.

NORTHFIELD.

Vermont Black Slate Company, Northfield.

CLAYS.

Clay has not been considered as one of the important products of Vermont. There are numerous brickyards in different parts of the state, but clay for other uses has been dug only in very small quantities until recently. At present, except for making brick, clay is dug only in two localities. At Forestdale in the east part of Brandon, there are quite extensive works carried on by Horn, Crockett and Company. The material here is kaolin, which is dug from pits and prepared for market in the well-equipped mill.

The Rutland Fire Clay Company owns extensive beds of various sorts of clay, from which the chief material for stove lining, wall plaster, fireproof roofing, etc., is obtained.

"This company was organized under the laws of Vermont in 1883, and has been in successful operation since that time. The business is mining and manufacturing clay products. Previous to 1903 its manufacturing was confined to furnace and foundry clays and fire cements. In the year 1903 the manufacture of a special patent wall plaster was commenced. The first year they sold $3,600 worth. The third year $54,000 worth. They own 225 acres of land, on which are practically inexhaustible deposits of nearly all of the raw materials used.

"These deposits are easy of access and convenient to railroads, a material advantage over all competitors in this respect. Their deposits of fire clays, mica schists, silicas, etc., are situated about two and one-half miles southeast of the center of the city of Rutland, and one and one-half miles east of the main line of the Rutland

Railroad, a branch of the New York Central, on which at this point are situated the main factory buildings. The deposits lie in alternating veins, extending nearly north and south about 3,000 feet, and east and west about 640 feet, varying in width from a few feet to several rods. The depth of the beds is unknown, but they have been worked more than fifty feet."

The above items have been kindly sent me in response to inquiries by Mr. A. W. Perkins, president of the company. Plates VII, VIII and IX show the mill storehouse and some of the clay pits of this company. There are several other buildings and clay banks not shown. In all there are over twenty buildings used in carrying on the work. The sales have increased 114 per cent during the year 1907, and thus far during 1908, that is, for the first six months, there has been a further increase of 47 per cent. The mill is well equipped for carrying on the manufacture of the materials sold by the company and is sufficient to produce them in much greater quantity. The wall plaster which is manufactured here appears to be very successful, and has received the highest commendation from architects and builders who have used it. Mr. Perkins has also furnished me with a copy of a report on the property of the company made in June, 1908, by Mr. I. K. Pierson, Engineer, New York City, from which I take the following extracts:

"*Clay Pits.*—The clay is deposited in beds of unknown depths at the beginning of the steeper mountain slopes, nearly southeast about two and one-half miles from Rutland. Two pits, about 1,600 feet apart, are opened and under exploitation, and from all visible evidence, lying on about the same level, and the deposits are connected, being one and the same vein.

"These pits are both opened from the sides of small gullies. Following the runs or creeks flowing from the hillsides, the surface outcroppings can be traced for a hundred feet, more or less, both above and below where laid bare by the water.

"The smaller, more northerly pit, is about 100 feet in diameter. It has been excavated to a depth of 30 feet.

"The second and larger pit has an average width of over 100 feet, and an east by west extension of about 400. The same conditions obtain here as in the smaller working, except that this mine shows a working depth of about 40 feet.

"The stripping of overlying material: This being so far of little

PLATE VIII.

Mills of Rutland Fire Clay Company.

tain that with more machinery at the pits and some sort of a tramway from them to the factory a much larger business could be done.

TALC.

This material occurs in many localities in this state, but often in only small quantities, and therefore of no special value. There are, however, several that have been more or less extensively worked during the past two years. Deposits of talc have been found large enough to attract some notice in Roxbury, Bridgewater, Lowell, Newfane, Rochester, East Granville, Chester, Moretown and Johnson.

At Moretown there is probably the most extensive plant for mining and working talc there is in the state, but there are mines worked at East Granville, Johnson, Rochester, and Windham.

The International Mineral Company have dug and ground a large amount of talc at their mine at Moretown. The Eastern Talc Company get out the material which is sent to mills elsewhere to be ground. The President, Mr. Freeland Jewett, writes me that they get out about 5,000 tons annually. He says:

"There is no doubt but that the Vermont talc is the smoothest and softest of any produced in this country, as the users constantly give it preference on this account to a product which is found further south. The whole problem of producing talc in a profitable way is governed by two points: one of which is getting rid of impurities and the other, having proper transportation facilities."

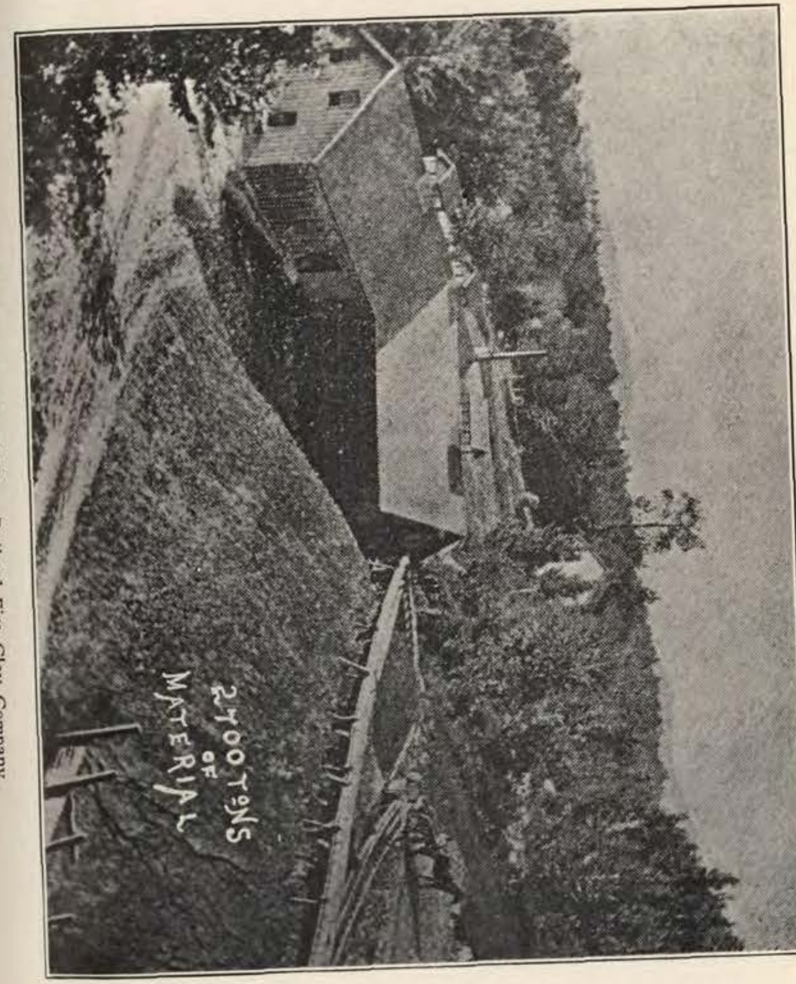
At Johnson, the American Mineral Company are vigorously mining a talc which appears to be of unusually good quality. The plant is able to turn out 2,000 tons annually. The enterprise has only recently been so far equipped that finished product could be turned out. Several hundred tons have been mined, ground and all of it sold since starting the machinery. The deposit appears to be extensive and the talc very free from grit.

The United States Talc Corporation have talc deposits at Rochester, but are not doing much as yet beyond the prospecting stage. Talc is also being mined at Windham.

SOAPSTONE.

Inasmuch as soapstone and talc are substantially the same, the former being a more compact and harder form of the mineral, they

PLATE IX.



Storehouse and Pile of Clay, Rutland Fire Clay Company.

are naturally found in the same places. The demand for steatite or soapstone or "freestone" has existed from earliest times, while talc has only within a short time been in demand, mainly as filling for paper. Soapstone is found in a greater number of places in this state than the talc variety, but is not worked, so far as I can discover, anywhere at present, except at Chester, Perkinsville and Weathersfield. The American Soapstone Finish Company work two quarries at Chester. The Union Soapstone Company have a quarry about three miles southwest of Chester and some seven hundred feet above it. These are, perhaps, the most largely worked soapstone quarries in the state.

"The soapstone occurs in seams or lenses bounded by a gneissic rock; they dip sharply to the southeast and strike nearly north and south. The lenses of soapstone also pitch toward the south. A thin seam of actinolite often occurs above the soapstone, between it and the gneiss. The soapstone has been opened by means of two cuts, the north one being 100 feet long by 70 feet wide and about 60 feet deep. The south cut or pit is 50–60 feet long, about 30 deep and 60–70 wide. The openings follow the pitching and dipping of the soapstone under the gneiss and although they have penetrated under it for some distance there is no timber used to support the roof. The blocks as they are quarried are hoisted to the surface, culled and then hauled to Chester Depot to the company's mill near the railroad. Ten and twelve miles northwest, north, and northeast of Chester Depot soapstone deposits have been opened along a line running from Ludlow to Perkinsville." Joseph H. Pratt, Mineral Resources, 1906, 1362.

The soapstone at Perkinsville occurs in very much the same way as that just mentioned at Chester. These quarries and the adjacent mill are carried on by the Vermont Soapstone Company.

The total amount of talc and soapstone sold annually in this state is not large, a little more than $100,000, but apparently it is likely to be greater in the immediate future. It may be well to note that Perkinsville is a village in Weathersfield.

ASBESTOS.

Asbestos, like soapstone and talc, occurs in many localities in this state, but it is mined at present only at property of the Lowell Lumber and Asbestos Company on the east side of Belvidere mountain.

This was formerly the property of M. E. Tucker and is mentioned as such in previous Reports.

This company, of which Mr. Wm. G. Gallagher is President, is actively engaged in mining and preparing for market the asbestos obtained from the rock of the mountain. A full report on the mineralogical and chemical character of this rock, and of the geology of the surrounding region, was published in the Fourth Report of the Geologist by Prof. V. F. Marsters, and to that those interested in the subject are referred.

The company above mentioned have several openings from which they take asbestos-bearing rock, and they have from these an overhead trolley by which the raw material is taken to crushers in the mill. This mill is 158 x 36 feet and several stories high. It is equipped with admirable machinery for crushing the rock and separating the fibrous portions. This separation is very effectively and ingeniously done by air blasts. Some of the machinery has been especially contrived for the purpose by Mr. E. B. Craven, the manager of the concern. Not only is the fiber thoroughly separated from the nonfibrous rock, but the different grades are also separated one from the others and carried each to its proper receptacle. The mill has at present a capacity for crushing fifty tons of rock per day and turning out about ten tons of separated fiber. The machinery now in place will when all in use increase the capacity of the mill threefold.

Mr. Gallagher writes as follows as to the products of the mill:

"After the four different grades of asbestos fiber are separated and deposited in their respective shoots, from the screenings of these there is remaining the pulverized fiber and rock which goes down over an aspirator and the remaining fiber is separated from the rock and this makes our number 5 material which is used for fireproof and sanitary flooring by being mixed with waterproof binder and applied in a plastic state. This when dry makes a hard and durable flooring, used quite extensively throughout Europe and only recently in this country. Our No. 6 material is the very fine pulverized fiber of nearly 2,000 mesh which is used in the manufacture of paints and for the insulation of wire. Our No. 7 material is composed of a part of the refuse fiber and the pulverized rock which, when mixed with other minerals, and a small quantity of coal tar, applied in a plastic state, makes one of the best roofing materials and is used extensively by a New York corporation. They guarantee a roof for twenty years, it being fireproof, waterproof and will not crack, disintegrate, nor require painting. The balance of the waste rock which is pulverized we shall use in the manufacture of insulators for electrical purposes at our own plant in the near future."

I have recently visited this property and was greatly pleased to find that in the mines the asbestos, and especially the cross fiber, was increasing decidedly in both quality and quantity, as deeper portions of the ledge were reached so that there is much to encourage the company in their undertaking.

Within a few days my attention has been called to a deposit of asbestos in the village of Mechanicsville. This appears to be like that on Belvidere Mountain, of the chrysotile variety, and while there has not as yet been work enough done to really show what there is yet, so far as can be inferred from as much as can be seen, there is promise of good fiber deeper down. That which now shows is some of it very good, but is mostly what is known as ship fiber, which is always less desirable than cross fiber. Speaking of these two sorts of fiber, Mr. J. S. Diller in Mineral Resources, 1907, page 1124, writes:

"Asbestos fiber, aside from its variation in mineral composition and the rocks with which it is associated, has two modes of occurrence according to which it is designated as cross fiber and slip fiber. Cross fiber asbestos forms veins in which the fiber extends directly across the vein, perpendicular to the vein walls. It is often silky and of high grade, ranging in size from a fraction of an inch to three inches in length. On the other hand slip fiber occurs in slickenside fault planes, produced by the slipping of one portion of serpentine or amphibole rock along its contact with another portion, generally of the same rock.

"The fibers produced as the result of the slipping lie in the slipping plane, hence the name. The mass of slip fiber in each plane may be a mere film to four or five inches in thickness, and varies in quality from long, smooth, flexible, tough fiber, excellent for textile purposes, to short, harsh, brittle fiber of small tensile strength. Cross fiber is generally, if not always, chrysotile. As far as yet known definitely, amphibole does not occur in distinct cross fiber veins. Cross fiber is for the most part of good quality, but the slip fiber, though often of chrysotile, varies greatly in its properties."

METALS.

COPPER.

The only metals produced in this state during the past year have been copper and a little silver, which latter was a sort of by product from the former. As most Vermonters know, there have been numerous attempts at profitable copper mining in the state for over fifty years. Some of these have been of considerable magnitude, and first and last a good many thousands of dollars must have gone into the copper mines, or what were supposed to be such. Some of the mines for a time paid expenses and considerably more, but the grade of ore, which is mostly chalcopyrite, is so low that in the long run it has not paid to work it. The only mine in the state which has been continuously worked for a long time is the old Elizabeth mine at South Strafford. I quote the following from the Montpelier Argus, after submitting it to one of the managers of the mine and receiving his endorsement of it as essentially correct:

"The Ely mines have been abandoned as unprofitable by the Westinghouse people after the expending of large sums of money for new machinery and in prospecting, but the South Strafford mines promise to be a paying proposition. A large cement dam is in process of construction a short distance below the village of Sharon, and the immense power developed is to be converted to the South Strafford mines. At the mines a modern smelter of 300 tons capacity is being constructed.

"A large tract of timberland was bought near the mines and a steam sawmill erected to manufacture the half million feet of lumber needed in constructing the smelter. Three and a half miles of new road have been built at considerable expense, and an elaborate water system with one reservoir of three and a half million gallons capacity and another smaller reservoir are to be constructed. An electric drive pump will be placed at the river for an auxiliary supply and a second pumping station is to be placed at the reservoir to supply a 30,000 gallon tank. At the large reservoir a pump for fire protection will also be placed, connected with a pipe line and hydrants throughout the plant.

"The plant will be electrically operated, consuming 500 to 600 horse-power continuously. Eight miles of transmission wire will be required to bring the power from Sharon to the plant, and another line to distribute power about the plant. Some fifty horse-power will be converted into direct current to operate electric cars, hoists, etc. A great many improvements are being made at the mines so as to get out a large tonnage of ore. When the plant is in operation a force of from 150 to 200 men will be employed. Freighting from Pompanoosac to the mines will be done by oxen, eighty large ones being used.

"The ore will be taken from the mines by an electric tram, then taken to the mill, where it is crushed and sampled with mechanical samplers. From there it is carried to bins close to the blast furnace by electric cars. These bins are very large, holding from two to three thousand tons of ore and coke. The ore is taken from these bins by means of electric weighing cars and fed into the side of the blast furnace.

"Immense slag pots, each holding three and one-half tons, will be used to remove the slag from the blast furnace. These slag pots will be pulled out by means of horses.

"The mat will be cast into moulds and crushed, taken to a crushing plant near the blast furnace building, where it will be crushed fine and there roasted in mechanical roasters. This mat will then be smelted to a higher grade of copper mat, to be shipped to the markets. The gases from the blast furnace will be taken away through a brick flue, 400 feet in length, and a stack 120 feet high and nine feet in diameter.

"The new company operating the Elizabeth mines is known as the Vermont Copper Company. August Heckscher is president."

A recent letter from one of the principal managers of the company says that "the transmission line and new furnace and other equipment at the mine are nearly all completed. The dam at Sharon and power house at Sharon will be completed this fall (1908). All machinery is on the ground ready to be installed."

According to "Mineral Resources," Vermont produced in 1906, 240,315 pounds of copper. I have no statements later, but probably during the past two years, 1907–8, the amount has not been as great, as the Pike Hill mines in Corinth, which for a few months produced a large amount of ore, have not been in operation.

SILVER.

Vermont has never, so far as I can ascertain, produced any silver until within a few years. It has been obtained in small quantity from the chalcopyrite and pyrrhotite which are mainly worked for copper. The total amount of silver produced in 1906 was 1,323 ounces, worth $886.

The Granites of Vermont.

T. NELSON DALE.

(This abstract of a forthcoming Bulletin by the U. S. Geological Survey is published here by arrangement between the Director of the Survey and the State Geologist of Vermont.)

During the summer of 1907 the writer visited all the operative granite quarries and some of the more important granite prospects of the state—seventy-nine in all—with a view to preparing a bulletin on Vermont granites on the plan and method of his two previous bulletins on the granites of Maine, and of Massachusetts, New Hampshire and Rhode Island, published by the United States Geological Survey. Although the manuscript of the Vermont Bulletin is not quite complete, it is sufficiently so to warrant the statements presented in this abstract.

The work is divided into two parts: (1) scientific and (2) economic. The first contains sections on the geographic distribution, general petrography, geological relations and earlier geological history of Vermont granites, followed by one on the important geological features at the quarries. This last includes chapters on double sheet structure, compressive strain, schist inclusions, contact phenomena, orbicular granite, and the delimonitization of "sap" on the under side of granite sheets. The second begins with a brief paragraph on the granite railroads, followed by descriptions of all the quarries and their granites, which are arranged by counties and under each county by townships. In the case of important granite centers like Barre and Woodbury there are introductory paragraphs on the topography, the general geology of the district, its typical granites and the geological observations at the quarries. These are followed by a description of each quarry, its exact location, dimensions, structural features, equipment, its granite in detail, and references to a few specimens of its finished product. The rest of Part 2 consists of chapters on the characteristics and adaptations, classification and commercial values of Vermont granites. Miss A. T. Coons of the United States Geological Survey contributes the statistics of production for the state and the book closes with a glossary of scientific and quarry terms and a bibliography of economic works on granite. The report will be illustrated by several plates showing the adaptation of the different granites to sculpture and the more interesting geological features at the quarries; also by a map of the Barre quarries and a number of minor sketch maps, sections and structural diagrams.

As the demand for any variety of granite depends largely upon its peculiar properties and as the commercial designations of these are often of a very general or commercial character, and, for that reason alone, in some cases unsatisfactory and misleading, there is need of a set of designations which shall not only be exact but removed from all suspicion of trade interest. For that reason the economically more important part of the report will probably be found to be its definitions of the various granites as to color, shade, texture, mineral composition and general qualities. These definitions of the typical granites of each district are therefore presented in this abstract.

The following acknowledgements are here due: Dr. Albert Johannsen, of the Survey, has assisted the writer in the more difficult microscopic determinations. The state geologist obtained the specimens from the prospects in Randolph and Rochester, which were not visited by the writer.

A few of the terms used require explanation: "Coarse" applied to the texture of granite includes granite with feldspars over 0.4 inch in diameter; "medium" that with feldspars under 0.4 and over 0.2 inch; and "fine" that under 0.2 inch. Quartz monzonite signifies a granite in which the amount of soda-lime feldspar about equals or exceeds that of the potash feldspar. Quartz monzonites usually cut or hammer very light.

The commercial granites of the state are technically of three kinds: Biotite granite, quartz monzonite and hornblende-augite granite. The granites of Woodbury, Newark and, with possibly one exception, of Barre belong to the first; those of Bethel, Randolph, Rochester, Calais, Derby, Dummerston, Hardwick (Buffalo Hill), Kirby, Groton, Topsham and a prospect in Cabot belong to the second; those of Ryegate belong to both first and second; and the green of Mount Ascutney, in Windsor, to the third.

CALEDONIA COUNTY.

Hardwick.—The Buffalo Hill quarry, on the hill of that name, is about 2½ miles S.60°W. of Hardwick village and about 500 feet above it. Operator, Hardwick Granite Co., Hardwick.

The granite, "Dark Blue Hardwick," is a quartz monzonite of dark gray shade, a little darker than "Dark Barre" and a trifle lighter than "Dark Quincy." Its texture is medium, with feldspars up to 0.3 inch and mica to 0.2 inch, generally even-grained but with sparse, clear, porphyritic feldspars up to 0.4 inch, inclosing other feldspars, quartz and mica. Its constituents, in descending order of abundance, are (1) smoky quartz with hairlike crystals of rutile and with fluidal and other cavities in sheets parallel to rift cracks and with another shorter and less frequent set at right angles to the first;* (2) milk-white soda-lime feldspar (oligoclase to oligoclase-andesine), much kaolinized, somewhat micacized and epidotized, with calcite; (3) in about equal amount to 2, a clear to bluish-white potash feldspar, some of it kaolinized, some inclosing particles of all the other minerals; (4) olive-colored biotite with a little muscovite or bleached biotite. The accessory minerals are pyrite, magnetite, apatite, zircon, rutile and allanite. The secondary minerals are kaolin, a white mica, epidote and calcite. The stone effervesces slightly with cold dilute muriatic acid.

This is a bright granite with strong contrasts between its white feldspar and black mica. Polishes fair. Hammers light, offering marked contrast to polished face. This shows some pyrite and magnetite.

Kirby.—The Grout quarry is on the south side of Kirby Mountain, 2½ or 3 miles N.20°W. of North Concord and about 450 feet above it. Operators, Carlton & Lake, East St. Johnsbury.

The granite is a quartz monzonite of light to medium, slightly bluish gray color and of medium inclining to fine, even-grained texture with feldspars up to 0.25 and mica to 0.1 inches. Its constituents, in descending order of abundance, are (1) light smoky quartz with fluidal and other cavities in sheets, with a set of cracks parallel to them; (2) milk-white soda-lime feldspar (albite to oligoclase-albite), much kaolinized, with some white mica; (3) clear to translucent bluish potash feldspar (microcline), with inclusions of 2, 1 and biotite; (4) biotite and a little muscovite or bleached biotite; accessory, zircon (magnetite and pyrite not detected); secondary, kaolin and a white mica.

*The relations of the rift and grain structure of granite to the sheets of cavities in its quartz particles are discussed and illustrated in Bulletin 354 of the U. S. Geological Survey, entitled, "The Chief Commercial Granites of Massachusetts, New Hampshire and Rhode Island," which is now in press.

The stone does not effervesce in cold dilute muriatic acid.

This is a bright granite but the fineness of its mica and the light shade of its smoky quartz preclude strong contrasts.

The Burke quarry is on the west foot of Kirby Mountain, about 2⅛ miles roughly N.50°W. of North Concord. Operator, Burke Granite Co. (Inc.), East Burke. The granite is a quartz monzonite closely resembling that of the Grout quarry.

The Kearny Hill quarry is about 1,000 feet S.60°W. from the above. Operator, Kearny Hill Quarry Co., Concord, Vt.

The granite is a quartz monzonite of light gray shade, with conspicuous fine black specks and medium inclining to coarse, generally even-grained texture, with feldspars up to 0.3 inches and mica to 0.2 inches, but with sparse, porphyritic, clear feldspars, embracing the other constituents, up to 0.5 inches. Its constituents, in descending order of abundance, are (1) clear, colorless quartz with hairlike crystals of rutile, and fluidal and other cavities in sheets; (2) bluish to milk-white soda-lime feldspar (oligoclase) somewhat kaolinized and micacized and inclosing much calcite; (3) clear potash feldspar (orthoclase and microcline) in large porphyritic plates, embracing all the other minerals; (4) biotite, some of it chloritized; (5) a little muscovite; accessory, pyrite, allanite, apatite, zircon, rutile; secondary, kaolin, a white mica, calcite, chlorite.

The stone effervesces with cold dilute muriatic acid.

Owing to the larger size of the biotite scales and the clearness of the quartz, the contrasts are more marked than in the Grout quarry stone. The sheen of the porphyritic feldspars is marked on the rough face.

Newark.—The Bugbee, Alexander & Packer prospect is in the eastern part of the town, on the west side of a ridge between Center Pond on the west and the east branch of the Passumpsic on the east. There is an east-west sag in the ridge. This locality is a little north of the sag, on a gently sloping bench below the steeper part of the ridge, 363 feet above Center Pond and about east-southeast from its south end. The intending operators are E. N. Bugbee and W. S. Alexander of Barre and H. D. Packer of Newark, Vt.

The granite is a biotite granite of light pinkish gray color and coarse, even-grained texture, with feldspars up to 0.8 inches and mica to 0.15 inches. Its constituents, in descending order of abundance, are (1) light pinkish gray potash feldspar (orthoclase and microcline), some of it intergrown with soda-lime feldspar or with inclusions of it, slightly kaolinized; (2) medium smoky quartz, with cavities in sheets; (3) cream-colored, in places slightly greenish gray, striated soda-lime feldspar (albite to oligoclase-albite), much kaolinized, with some white mica and calcite; (4) biotite, some of it chloritized; accessory, magnetite, pyrite, titanite, allanite; secondary, kaolin, a white mica, epidote, calcite.

The rock effervesces slightly with cold dilute muriatic acid. Mr. W. T. Schaller, of the chemical laboratory of the United States Geological Survey, finds that it contains 0.23 per cent of CaO (lime) soluble in warm dilute acetic acid (10 per cent), which indicates a content of 0.41 per cent of $CaCO_3$ (lime carbonate, calcite), the presence of which mineral is also shown by the microscope.

The contrasts are chiefly between the smoky quartz and the combined feldspars. The rock has very sparse porphyritic feldspars up to 1.5 by 0.5 inches, but these are hardly numerous enough to impart to it a technically porphyritic texture. The polished face shows magnetite in minute particles and a very few of pyrite. The polish is fairly good, the mica particles, although somewhat large, not being very abundant.

Ryegate.—The granites of Blue Mountain in Ryegate are quartz monzonite and biotite granites of light and medium, more or less bluish-gray color, and of medium (very rarely fine to medium), even-grained texture, and are used chiefly for rough or hammered monumental work.

The Morrison quarry is on the southwest side of Blue Mountain, about 940 feet above the village of South Ryegate. Operator, D. A. Morrison & Co., South Ryegate.

The granite is a quartz monzonite of medium gray shade and medium, even-grained texture, with feldspars up to 0.4 and mica to 0.2 inches. Its constituents, in descending order of abundance, are (1) very light smoky quartz, with hair-like crystals of rutile and cavities in sheets arranged in two rectangular directions with cracks parallel to each set; (2) milk-white soda-lime feldspar (oligoclase), somewhat kaolinized, with some white mica and rarely epidote; (3) bluish translucent potash feldspar (microcline); (4) biotite and a little muscovite or bleached biotite; accessory, zircon, apatite, rutile; secondary, kaolin, epidote, a white mica and calcite, as shown by muriatic acid test. Although the contrasts in this granite are feeble, the smoky quartz is somewhat conspicuous.

The stone of the adjoining Gibson, Italian and Tupper quarries is identical with the above, or will be as these quarries deepen.

The stone of the Frazer quarry (formerly Hall's), on the southwest side of the southeast spur of Blue Mountain, is a quartz monzonite of light to medium gray shade and of medium inclining to coarse, even-grained texture, with feldspars up to 0.4 inches and mica to 0.2 inches. The contrasts between its minerals are much more marked than in the stone of the Morrison quarry.

The Rosa quarry is on the northeast side of the southeast spur of Blue Mountain, and about 1,100 feet above the village of South Ryegate.

The granite is of two kinds: (a) biotite granite of medium gray shade and of fine inclining to medium, even-grained texture, with feldspars up to 0.2 inches and mica to 0.1 inches. Its general shade is slightly darker than that of the quartz monzonite of the quarries on the southwest side of the mountain. Its constituents, in descending order of abundance, are (1) translucent very light, bluish-gray potash feldspar (orthoclase and microcline); (2) light smoky quartz, with hairlike crystals of rutile and fluidal and other cavities in sheets with cracks parallel thereto; (3) whitish soda-lime feldspar (oligoclase), slightly kaolinized, micacized and epidotized; (4) biotite and a little muscovite or bleached biotite; accessory, apatite, zircon, titanite, rutile; secondary, kaolin, a white mica, epidote, calcite, limonite.

Mr. W. T. Schaller, of the chemical laboratory of the United States Geological Survey, finds that this stone contains 0.03 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.08 per cent of $CaCO_3$ (lime carbonate). The fineness of its texture precludes contrasts between its minerals.

The other granite from this quarry (b) is a biotite granite of medium bluish-gray shade and medium, even-grained texture, with feldspars up to 0.3 inches and mica to 0.15 inches. Its shade is slightly darker than that of the Morrison quarry stone, owing to its more abundant biotite. Its contrasts are also stronger. It effervesces with cold dilute muriatic acid.

Groton.—The Benzie quarry is about a mile S.25°W. of the Wells

River bridge at Groton village and 300 feet above it. Operator, McCrae Benzie & Co., Groton, Vt.

The granite "Vermont Blue" is a quartz monzonite of medium, quite bluish-gray color and even-grained, medium inclining to fine texture. Its constituents, in descending order of abundance, are (1) clear, colorless to very light smoky or very light bluish quartz, with few cavities and with brightly polarizing rift and grain cracks; (2) light bluish, translucent soda-lime feldspar (oligoclase), somewhat kaolinized and with white mica in fibers and scales, also some calcite; (3) a little clear potash feldspar (microcline, possibly also orthoclase), with inclusions of oligoclase, quartz and biotite; (4) biotite and a little muscovite or bleached biotite; accessory, titanite, pyrite, zircon, apatite, allanite; secondary, kaolin, a white mica, calcite, leucoxene.

The stone effervesces with cold dilute muriatic acid. It is brilliant and markedly bluish, but its contrasts are feeble owing to the fineness of its texture and the similarity in the shade of its quartz and feldspar.

ORANGE COUNTY.

(The granite of Williamstown, near Barre, is included with that of Washington County.)

Randolph.—Beedle's Prospect is in the west corner of the town, between the Bethel line and the west branch of the White River, three fourths mile west and southwest of the Vermont Central Railroad, which here describes a curve. It is on the farm of A. H. Beedle of Randolph.

The granite, fine white, is a quartz monzonite of extremely light gray shade, without any mica spots. It is lighter than Dummerston "White," but not so white as the granite of Bethel when the rough faces are compared and its slight grayness has a faint tinge of green in it. Its texture is even-grained and fine, with feldspars nearly all under 0.1 inches and none over 0.15 inches. Its constituents, in descending order of abundance, are (1) milk-white striated soda-lime feldspar (albite to oligoclase-albite), more or less kaolinized and micacized, some of it intergrown with potash feldspar (microcline), the latter, however, forming but a small portion of the particle; (2) clear, colorless quartz with fluidal and other cavities, rarely with hairlike crystals of rutile; (3) very little separate potash feldspar (microcline); (4) muscovite in scales up to 0.37 millimeters; accessory, zircon, apatite, rutile; no magnetite or pyrite detected; secondary, kaolin, a white mica, epidote and zoisite in rather abundant, irregular particles up to 0.5, exceptionally 0.75 millimeters. A little calcite, and rare chlorite scales up to 0.22, exceptionally 0.75 millimeters. The epidote is really the fifth mineral in order of abundance and accounts for the slight greenish tinge of the rock, which is reënforced by the chlorite.

The stone effervesces slightly with cold dilute muriatic acid. Mr. W. T. Schaller, of the chemical laboratory of the United States Geological Survey, finds that it contains 0.37 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.66 per cent of $CaCO_3$ (lime carbonate, calcite), the presence of which mineral is also shown by the microscope.

The stone takes a high polish, as the absence of all but very minute mica plates implies. Being a quartz monzonite and also free from mica spots, it will probably hammer quite as white as the quartz monzonite of Bethel. The specimen shows rift or flow structure.

ORLEANS COUNTY.

Derby.—The Newport Granite Company's quarry is near the center of the town and about four miles roughly east of the city of Newport, on Lake Memphremagog. Operator, Newport Granite Co., Newport.

The granite is a quartz monzonite with both biotite and muscovite, of light bluish-gray color and even-grained, medium inclining to fine texture, with feldspars up to 0.25 and 0.3 and mica to 0.15 inches. Its constituents, in descending order of abundance, are (1) light smoky quartz, with hair-like crystals of rutile and fluidal and other cavities in sheets, with cracks parallel to and in places coinciding with them; (2) clear to bluish milk-white striated soda-lime feldspar (albite to oligoclase), mostly much kaolinized and somewhat micacized; (3) clear to translucent, bluish potash feldspar (microcline), slightly kaolinized; (4) biotite; (5) muscovite; accessory, apatite, titanite, allanite, rutile; no magnetite or pyrite detected; secondary, kaolin, a white mica and calcite.

There is no effervescence with cold dilute muriatic acid, but Mr. W. T. Schaller, of the United States Geological Survey, finds that the stone contains 0.05 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.09 per cent of $CaCO_3$ (lime carbonate, calcite).

The shade of this granite is between that of "Light Barre" and that of Hallowell, Me. It has more black mica than "Light Barre" and stronger contrasts. These are between the black mica, the feldspar and an intermediate shade formed by the muscovite and quartz together.

WASHINGTON COUNTY.

(The granite of Williamstown in Orange County will be included with that of Barre, of which it forms a part.)

Barre.—About three miles southeast of the city of Barre is a roundish granite mass, known as Millstone Hill, rising to a height of 1,200 feet (by aneroid) above Barre. About 2 miles north-northeast of that mass and 2½ miles east-southeast of Barre is another granite mass known as Cobble Hill, which is 1,100 feet above Barre. Fifty-six quarries or openings are grouped about Millstone Hill and four about Cobble Hill.

Barre Granite is known commercially as "Dark," "Medium" and "Light Barre," with some exceptional "Very Dark" and "White." It is everywhere (except possibly in one quarry the granite of which is still being investigated) a biotite granite and these shade designations have arisen partly from its varying content of biotite and partly from the various degree of kaolinization and micacization of its soda-lime feldspar, causing it to range from a bluish-gray to a milk-white. These shades are here technically designated as follows: (1) *Very light gray* (Wheaton quarry, Cobble Hill), equivalent to North Jay, Me., granite; (2) *light inclining to medium, slightly bluish gray* (Jones light quarry) between "North Jay" and "Hallowell," Me.; (3) *light medium bluish-gray* (Smith upper quarry) between "Hallowell" and "Concord," N. H.; (4) *medium bluish-gray* (Duffee quarry), a trifle darker than "Concord"; (5) *dark inclining to medium bluish-gray* (Bruce quarry); (6) *dark bluish-gray* (Marr & Gordon quarry); (7) *very dark bluish-gray* (Marr & Gordon "knots"), equivalent to "Dark Quincy." The chief product of the Barre quarries consists of shades 2, 3, 4 and 5.

Its texture ranges from fine to medium—that is, with feldspars up to 0.2 and 0.4 inches, generally, however, not exceeding 0.2, few reaching 0.3 inches, so that it may be generally designated as fine

inclining to medium or medium inclining to fine. The light granite of the Bond & Whitcomb quarry on Millstone Hill and of the Wheaton quarry on Cobble Hill are of medium texture, with feldspars up to 0.4 inches. The mica particles of Barre granites range up to 0.1 and 0.2 inches, but in the very dark to 0.3 inches.

Its constituent minerals, in descending order of abundance, are (1) clear, colorless or bluish to translucent potash feldspar (microcline with or without a little orthoclase, rarely minutely intergrown with a little soda-lime feldspar); (2) light smoky quartz, showing optical effects of strain, rarely with hair-like crystals of rutile, generally with fluidal and other cavities in sheets with rift cracks parallel to or coinciding with them, and in some specimens with fewer and shorter sheets of such cavities intersecting the first set at right angles and with grain cracks parallel to them. In one specimen the rift cracks continue into the feldspar and are there filled with fibrous muscovite; (3) bluish translucent to milk-white soda-lime feldspar (albite to oligoclase-albite, in some sections with flexed twining lamellae), considerably kaolinized and micacized and with plates of calcite; (4) biotite, some of it chloritized, and a little muscovite or bleached biotite. The accessory minerals include pyrite, magnetite, titanite, allanite, apatite, zircon, rutile. The secondary minerals are kaolin, a white mica, calcite, epidote, chlorite. Exceptionally there are minute veins of quartz, of calcite and of epidote.

All the Barre granites effervesce with cold dilute muriatic acid. Mr. W. T. Schaller, of the United States Geological Survey, finds that the "light" contains 0.49 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, and the "dark" 0.13 per cent of it, which indicates a content of 0.87 and 1.12 per cent respectively of $CaCO_3$ (lime carbonate, calcite), the presence of which mineral is also shown by the microscope.

Barre granite is mostly monumental; some of it (Bond & Whitcomb and Wheaton quarries) is constructional granite. The light, medium and dark monumental granites, although brilliant, have weak mineral contrasts in the rough. These are stronger on the polished face of the dark. The white of the more altered soda-lime feldspars, and the black of the mica, and the combined, bluish-gray of some of the feldspar and smoke color of the quartz, form three distinct shades, but owing to the fineness of texture they merge a few feet away and the white feldspar alone shows against a dark gray ground. "Light Barre" granite is never polished, but is hammered, because of the weak contrast between its polished and cut surface, yet the dark is often used for polished work. Its polish is fair. The contrast between the polished and cut face of the dark is more marked along the "hardway" than along the rift or grain directions. The polished face shows pyrite and magnetite.

Cabot.—Lambert's quarry is in the north corner of the town, on the east side of a north-south ridge, roughly about 4 miles east of Robeson Mountain, in Woodbury, and about 700 feet above Woodbury Pond. It is on the farm of Myron Goodnough, near the Walden line, on the South Walden road which leads from Cabot to Hardins. Operator, Joseph Lambert, Macksville, Hardwick.

The granite is a quartz monzonite of dark bluish-gray color (as dark as "Dark Barre") and of even-grained, fine texture, with feldspar and mica up to 0.2 inches, the latter rarely 0.3 inches. Its constituents, in descending order of abundance, are (1) clear quartz with fluidal and other cavities in sheets and rift cracks parallel to them filled with fibrous muscovite and extending into the feldspars; (2) bluish-gray to milk-white soda-lime feldspar (oligoclase), but little kaolinized, micacized and with calcite; (3) bluish-gray potash feldspar (microcline and possibly orthoclase); (4) greenish biotite and a little muscovite or bleached biotite; accessory, pyrite, apatite, titanite, allanite; secondary, epidote, a white mica, kaolin, calcite.

The stone effervesces very slightly with cold dilute muriatic acid. It is a little finer textured than some of the "Dark Barre" and more micaceous. Its contrasts are also more marked, owing to its feldspars being whiter and less bluish and its quartz not smoky. It ought to hammer very light.

Calais.—The Patch quarry is about half a mile from Adamant (formerly Sodom), in the western corner of the town, and 6 miles north-northeast of Montpelier. Operator, Patch & Co., Montpelier.

The granite is a quartz monzonite of medium, slightly bluish-gray color and of even-grained, medium texture, with feldspars up to 0.3 inches, rarely 0.4 inches, and mica to 0.1 inches. 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 (1) clear, colorless quartz with but few cavities in sheets; (2) clear, colorless potash feldspar (orthoclase and microcline), with inclusions of soda-lime feldspar, biotite and quartz; (3) in about the same amount, bluish to milk-white soda-lime feldspar (oligoclase-albite), micacized and somewhat kaolinized and with calcite; (4) biotite and a little muscovite or bleached biotite; accessory, apatite, zircon; secondary, kaolin, a white mica and calcite.

The stone effervesces slightly with cold dilute muriatic acid. This granite is of the same shade as "Medium Barre," but of less bluish and more greenish tinge. Its contrasts are stronger and its texture is a little coarser. Its large, clear feldspars give brilliancy to its rough surface.

The Lake Shore quarry, also near Adamant, is about 1,200 feet S.32°W. of the Patch quarry. Operator, Lake Shore Quarry Co., Montpelier. The granite has the same constituents as those of the Patch quarry stone, with the addition of secondary epidote in particles up to 0.5 millimeters. It is slightly darker than "Light Barre" and somewhat lighter than "Medium Barre." Its shade corresponds to that of Hallowell, Me., granite but its contrasts are stronger.

The stone of the Eureka quarry, which lies about 900 feet N.30°E. from the Patch quarry, is presumably identical with the stone of that quarry.

Woodbury.—Woodbury granites are all biotite granites of more or less bluish-gray shade, ranging from dark to light (one very light cream color) and in texture from very fine to medium. They fall into four kinds but, taking account of minor differences, into nine varieties. Most of them possess in large masses one general characteristic. They carry sparsely distributed more or less incomplete crystals up to an inch across of clear potash feldspar formed about the other minerals. There is some parallelism between these crystals for at a certain angle the cleavage planes of adjoining crystals reflect the light with equal brilliancy.

The granites of Robeson Mountain consist, in descending order of abundance, of (1) clear to translucent bluish potash feldspar (orthoclase and microcline), rarely somewhat kaolinized, its larger particles with inclusions of biotite, quartz and soda-lime feldspar; (2) light to medium smoky quartz with hair-like crystals of rutile and fluidal cavities in sheets arranged in two rectangular directions parallel to rift and grain cracks respectively. Some of the rift cracks extend into the feldspar and are filled with fibrous muscovite. (3) Milk-white soda-lime feldspar more or less kaolinized, micacized and with calcite, and less frequent epidote; (4) biotite, some of it chloritized, and a little muscovite or bleached biotite;

accessory, pyrite, titanite, zircon, apatite, rutile; secondary, kaolin, a white mica, epidote, zoisite, calcite, limonite.

The stone of Robeson Mountain is of three varieties. That of the Fletcher quarry is of light gray shade (between "Light Barre" and Hallowell, Me.) and of medium texture with feldspars up to 0.3 inches and mica to 0.1 inches. Its quartz is medium smoky and its contrasts marked. That of the main quarry of the Woodbury Granite Company is of medium gray shade and medium texture also, but its quartz particles are a little finer, less numerous and less smoky than the above. Its contrasts are therefore weaker. The polish is poor owing to abundant and rather large mica scales, but the contrasts on the polished face are strong. It shows a little pyrite. The stone of the Woodbury Company's upper quarry, "Woodbury Bashaw," is of medium gray shade (about like Concord, N. H., granite, but more bluish and with more contrasts) and of fine inclining to medium texture, with feldspars up to 0.2 and mica to 0.1 inches. Its contrasts, either on rough or polished face, are not as marked as in the two other stones. This is because the feldspars are less altered and thus more bluish. Its texture is finer and its polish better, but it shows also a little pyrite.

Mr. W. T. Schaller, of the United States Geological Survey, finds that the Fletcher quarry granite contains 0.16 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 0.28 per cent of $CaCO_3$ (lime carbonate, calcite), the presence of which mineral is also shown by the microscope in this and the "Woodbury Bashaw."

Another kind of Woodbury granite occurs at the new Drennan and Webber openings and at an old one near Buck Pond. It is of dark bluish gray color and fine texture, with feldspars up to 0.2 inches and mica to 0.1 inches. Its composition is identical with that of the Robeson Mountain granites but its quartz is clear and its soda-lime feldspar is albite to oligoclase-albite. Its shade corresponds to that of "Dark Barre," but its texture is finer.

Still another kind occurs at the Nicols Ledge Carter quarry. It is of light inclining to medium bluish-gray color and of very fine to fine texture with feldspars up to 0.15 and mica to 0.1 inches. This is a finer and lighter-shaded stone than the last. Its quartz is clear with apatite needles and its soda-lime feldspar is oligoclase to oligoclase-andesine.

Finally, there is a very light, slightly cream-colored constructional granite prospected between Robeson Mountain and Buck Pond, not far from the Drennan quarries. It is of medium texture and speckled with sparse black mica to 0.15 inches. Its quartz is pale smoky.

WINDHAM COUNTY.

Dummerston.—The Black Mountain quarry, at the southwest foot of Black Mountain, 5 miles north-northwest of Brattleboro, is operated by the George E. Lyons Co., West Dummerston.

The granite, of two sorts, chiefly "White, West Dummerston, Vt.," is a quartz monzonite of very light gray shade, speckled with bronze-colored mica (muscovite and biotite), and of even-grained, medium texture, with feldspars up to 0.3 and mica to 0.1 inches. Its constituents, in descending order of abundance, are (1) clear to pale smoky quartz, showing effects of strain, with hair-like crystals of rutile and a few fluidal cavities in sheets; (2) milk-white soda-lime feldspar (oligoclase-albite, with some flexed twinning lamellae), kaolinized and micacized; (3) clear potash feldspar (microcline and possibly orthoclase); (4) muscovite and less biotite, apparently intergrown and bent or twisted with fibrous muscovite stringers extending out from them into and between other particles; accessory, apatite, rutile; secondary, kaolin, white micas, epidote, zoisite, calcite. There are crush borders about the quartz and feldspar particles.

This stone effervesces slightly with cold dilute muriatic acid. Mr. W. T. Schaller, of the United States Geological Survey, finds that it contains 0.07 per cent of CaO (lime) soluble in warm, dilute (10 per cent) acetic acid, which indicates a content of 0.125 per cent of $CaCO_3$ (lime carbonate, calcite), the presence of which mineral is also shown by the microscope.

This is a constructional granite of medium grain and very light shade, between that of North Jay, Me., and of Bethel in whiteness.

The other granite, "Dark Blue," is a quartz monzonite of light inclining to medium bluish-gray color and of even-grained, fine inclining to medium texture with feldspars up to 0.2 inches and mica to 0.1 inches. Its constituents are the same as those of the other but its oligoclase-albite is bluish and less altered, and its mica nearly all muscovite. It shows less calcite and does not effervesce with cold dilute muriatic acid. This is a monumental granite of light bluish gray tint and without contrasts.

The Clark quarries east of West Dummerston, on the northwest side of Black Mountain, are operated by James Clark of West Dummerston.

The granite from the lower opening differs from the "white" of the "Black Mountain Quarry" in that the biotite is more prominent and the fibrous muscovite absent. The stone of the upper quarry is identical with the "white" referred to.

The Bailey Prospects, owned by David J. Bailey, Brattleboro, R. F. D., are about half a mile south-southwest of the Black Mountain quarry, on the west side of West River.

The granite from an opening about 200 feet above the main road to Brattleboro is a quartz monzonite of light gray shade and medium inclining to fine, even-grained texture with feldspars up to 0.25 and mica mostly under 0.05 inches, and more thickly disseminated than in the "White" of Black Mountain. Its constituents are the same but the quartz is more smoky, the mica mostly biotite with but little muscovite or bleached biotite. The fibrous muscovite and crush borders are lacking.

This stone is of slightly finer texture and, owing to the smokiness of its quartz, and the distribution and amount of its biotite, of slightly darker shade than the "White" of Black Mountain. It is lighter than "Light Barre."

A granite ledge a little north-northwest of this is crossed by a 30-foot dike of fine granite. This stone, although probably harder than ordinary granite, may be found of economic value. It is a quartz monzonite of similar composition as that of Black Mountain but of medium, bluish-gray shade and of very fine, even-grained texture with feldspar and mica up to 0.05 inches. In thin section its particles range from 0.074 to 1.1 millimeters in diameter. Its mica is chiefly biotite. The soda-lime feldspar is bluish-gray and scarcely altered. There are crush borders.

WINDSOR COUNTY.

Bethel.—The granite of Bethel, although known under the commercial name of "Bethel White Granite" (which has been copyrighted) and sold by another firm as "Hardwick White Granite," as its main office is located at Hardwick, is one and the same granite. The two quarries, but 50 feet apart, are excavations in granite of one mass of contemporaneous origin and of identical composition and texture. The following description is based upon specimens, rough and polished, and thin sections from both quarries.

The granite of Bethel is a quartz monzonite of slightly bluish milk-white color, with grayish spots up to 0.3 inches and of coarse inclining to medium texture, with feldspars up to 0.4 inches and 0.5 inches and mica to 0.3 inches. Its constituents, in descending order of abundance, are (1) bluish milk-white soda-lime feldspar (oligoclase), slightly kaolinized and micacized; (2) clear, colorless, rarely bluish quartz with hair-like crystals of rutile, and with fluidal and other cavities in sheets with cracks parallel to them; (3) very little clear potash feldspar (microcline); (4) muscovite; (5) very little biotite; accessory, apatite, titanite, zircon, rutile; no magnetite or pyrite detected; secondary, kaolin, a white mica, epidote and zoisite in some abundance, and very little calcite.

The stone does not effervesce with dilute muriatic acid, but Mr. W. T. Schaller of the chemical laboratory of the United States Geological Survey, finds that it contains 0.07 per cent of CaO (lime) soluble in warm, dilute (10 per cent) acetic acid, which indicates a content of 0.125 per cent of $CaCO_3$ (lime carbonate, calcite), which is very slight.

The stone is regarded as relatively hard by workmen. Its grade of whiteness is shown by these comparisons: The "White Granite" of North Jay, Me., is technically *very light gray*. The "White" of West Dummerston is a trifle lighter. That of Randolph lighter yet, and the Bethel stone is still lighter, more strictly, *white mottled with gray*. Its white is more blue than ordinary Vermont marble, but is closely allied to its "blue" variety, not its bluish-gray varieties. Owing, probably, to the abundance of its soda-lime feldspar, its hammered face is considerably whiter than its rough face and the hammering also diminishes the prominence of the gray micaceous spots. It takes a high polish but the effect of polishing is to make the mica spots more conspicuous than they are even on the rough face. The polished specimens handled by the writer do not show any pyrite or magnetite. The sheets at both quarries are free from rusty borders excepting at the headings.

Windsor.—The green granite of Mount Ascutney is now quarried only at the Mower quarry, on the west side of the mountain, nearly a mile and a quarter south of Brownsville. Operator, Ascutney Mountain Granite Co., Windsor.

The granite is a hornblende-augite granite of dark olive green color and of medium texture, with feldspar up to 0.3 inches and black silicates to 0.2 inches. As shown by Daly, the color of the freshly-quarried feldspar is a bluish-gray but on exposure this rapidly changes to dark green.* The constituents of the section examined by the writer are, in descending order of abundance (1) dark olive green potash feldspar (orthoclase), minutely and obscurely intergrown with soda-lime feldspar (oligoclase); (2) dark smoky quartz with cavities some in streaks and sheets, and with cracks filled with limonite; (3) hornblende, usually associated with 4; (4) augite; accessory, titanite, magnetite, zircon; secondary, white mica in feldspar, limonite in cleavage and other cracks.

The stone does not effervesce with cold dilute muriatic acid. Owing to the absence of mica, it takes a very high polish, quite as high as that of Quincy granite. Its polished face is much darker than its rough face, but the hammered or cut face is much lighter than either so that lettering or carving stands out boldly on the polished face.

Rochester.—The Pierce Prospect is 3 miles south of Rochester village, the western terminal of the White River Valley railroad, and on the Rochester-Pittsfield town line. The out-crop extends a little ways into the town of Pittsfield in Rutland County. Prospective operator, White River Granite Co. (E. L. Pierce), Rochester, Vt.

The granite is a quartz monzonite of slightly greenish-white color, with conspicuous brilliant muscovite spots up to half an inch in diameter, and of coarse texture, with feldspars to 0.5 inches. The muscovite spots, being aggregates of mica scales, have a peculiar sheen. As they are not over 0.04 inches thick and lie with their flat sides roughly parallel the rock has a somewhat gneissoid texture. Its constituents, in descending order of abundance, are (1) milk-white to slightly greenish soda-lime feldspar (albite to oligoclase-albite), somewhat kaolinized and with thickly disseminated white mica scales up to 0.15 millimeters long, and not a few plates of calcite; (2) clear, colorless to pale bluish quartz, rarely with hair-like crystals of rutile, and with fluidal and other cavities in two rectangular sets of sheets, one with many more cavities than the other; (3) Muscovite in large flakes and aggregates of such.

The stone effervesces with cold dilute muriatic acid and Mr. W. T. Schaller, of the United States Geological Survey, finds that it contains 1.38 per cent of CaO (lime) soluble in warm dilute (10 per cent) acetic acid, which indicates a content of 2.46 per cent of $CaCO_3$ (lime carbonate, calcite), the presence of which mineral is shown by the microscope.

*Daly, R. G. "The Geology of Ascutney Mountain, Vermont." U. S. Geol. Survey Bull. 209, 1903, p. 51.

This is a constructional granite of very light, pale greenish gray color with striking contrasts produced by large mica spots, the brilliancy of which on the fresh rift face is almost metallic. Whether its somewhat gneissoid texture and its content of nearly 2½ per cent of calcite are serious obstacles to its constructional use can only be determined by compression tests and continued exposure to the weather.

Although the outcrop is 3 miles from Rochester station, its distance from the nearest point on the railroad is about a mile.

Essex County ?

Fossil Cetacea of the Pleistocene of the United States and Canada,

WITH SPECIAL REFERENCE TO

Delphinapterus vermontanus, Thompson.

G. H. Perkins.

The Fossil Whale in the State Museum at Montpelier, Vermont, has been for many years one of the most interesting specimens ever discovered in this State. It has for several years seemed to the writer that a more careful study and complete illustration than this specimen has hitherto received is desirable. Soon after this was commenced a request came from Dr. F. W. True of the U. S. National Museum that a series of photographs of the Vermont specimen be taken for the use of the Museum.

This was done and through the courtesy of Dr. True and Dr. Rathburn, Director of the Museum, the author was allowed to use copies of these photographs for illustrating the following paper. Not all, but many of the accompanying plates are from this source.

The author is also indebted to Dr. True for most generously placing at his disposal manuscript material which he had collected referring to the Vermont specimen and also for valuable suggestions and examination of the photographs. Acknowledgements are also due to Mr. Roy C. Andrews of the American Museum of Natural History for important assistance in comparing different fossil bones with those of recent species, to Mr. Harry Piers, Curator of the Provincial Museum, Halifax, N. S., to Dr. J. F. Whiteaves and Mr. L. M. Lambe of the Geological Museum at Ottawa and to Mr. Edward Ardsley, Assistant Curator of the Peter Redpath Museum of McGill University, Montreal, for most freely giving opportunity for examining the specimens in those museums. Through the great kindness of these gentlemen the author has been able to study all the existing specimens of North American Cetacea which have been found in the Pleistocene, excepting only a few scattered bones and the southern species mentioned by Mr. Hay in the reference on page 79.

At the outset the author had no thought of considering other specimens than the nearly complete skeleton at Montpelier, but as his investigations progressed it was found interesting and important to study as many specimens as possible of both recent and fossil cetacea and the results of this work are presented in the following pages.

So far as I am aware only a few isolated cetacean bones have been found in the Pleistocene this side of the Canada line, except those of the Montpelier specimen, but in Canada more or less complete skeletons of several individuals have been found at different times, as will be seen in what follows. All but one of these Canadian specimens have been, I believe, identified with either the Vermont specimen or the recent *Delphinapterus leucas*. As I have examined the grounds on which these identifications rest most of them seemed to be very uncertain. Anyone who has studied the skeletons of living cetacea to any extent has soon become convinced of the difficulty, which in many cases amounts to impossibility, of satisfactorily determining the specific identity of two skeletons, or parts of them, unless there is opportunity to make direct comparison of the bones. Even then it is not always easy to arrive at certainty. The difficulties arise from the considerable individual variation in the same species and in a greater or less general similarity which is found in skeletons of different species or even genera. Further comments on these identifications will appear later. The following bibliography of the genus *Delphinapterus,* taken mostly from Bulletin 179, U. S. Geol. Survey, by Mr. O. P. Hay, although made out for the genus named, yet includes most of the Pleistocene Cetaceans which have been found in North America, at least as far as the author has been able to ascertain:

1. *Delphinus vermontana* Z. Thompson, Am. Jour. Science, 2d Series, Vol. IX, pp. 256–263, 1850.

2. *Beluga vermontana* Z. Thompson, Appendix, Thompson's Vermont, pp. 15–20, figs. 1–13, 1853.

3. *Beluga vermontana* Thomp. C. H. Hitchcock, Geology of Vermont, Vol. I, pp. 162–165, 1861.

4. *Beluga vermontana* Thomp. A. D. Hager, Geology of Vermont, Vol. II, p. 938, fig. 340.

5. *Beluga vermontana* Thomp. W. E. Logan, Superficial Geology of Canada, Geological Survey of Canada, p. 919, 1863.

6. *Beluga vermontana* Thomp. E. D. Cope, Proceedings Acad. Nat. Science, Philadelphia, pp. 138–156, 1867.

7. *Beluga vermontana* Thomp. J. Leidy, Journal Acad. Nat. Science, Phil. 2 VII, pp. 1–472, 1869.

8. *Beluga vermontana* Thomp. E. Billings, Canadian Naturalist and Quar. Journal of Science, Vol. V, pp. 438–439, 1870.

9. *Beluga vermontana* Thomp. E. D. Cope, Am. Naturalist, Vol. V, p. 125, 1871.

10. *Beluga vermontana* Thomp. J. F. Brandt, Memoirs, Imp. Acad. Science, St. Petersburg, Vol. XX, no. 1, pp. I–VIII, 1–372, Plates 1–24, 1873.

11. *Beluga vermontana* Thomp. B. Gilpin, Nova Scotia Institute of Nat. Science, Vol. II, pp. 400–404, 1873.

12. *Beluga vermontana* Thomp. D. Honeyman, Am. Jour. Sci., 3d Ser. Vol. VI, p. 597, 1874, also Vol. VIII, p. 219, 1874.

13. *Beluga vermontana* Thomp. J. W. Dawson, Acadian Geology, Supp. p. 28, 1878.

14. *Beluga vermontana* Thomp. J. W. Dawson, Am. Jour. Sci. 3d Ser., Vol. XXV, p. 200, 1883.

15. *Delphinapterus vermontana* Thomp. E. D. Cope, American Naturalist, Vol. XXIV, p. 616, 1890.

16. *Delphinapterus leucas* Gray. J. D. Dana, Manual of Geology, fourth ed., p. 983, fig. 1561, 1896.

17. *Delphinapterus* (*Beluga*) *catodon* Dawson. Canadian Record of Science, Vol. VI, p. 351, 1896.

18. *Delphinapterus vermontana* Truessart Catalogue, Mammalium, Vol. II, p. 1,951, Supp. p. 771, 1898.

19. *Delphinapterus vermontana* Whiteaves, Ottawa Naturalist, Vol. XX, pp. 214–216, 1907.

From information given in the foregoing references, and still more from personal inspection of specimens in the several museums in which they have been placed we learn that there are in existence the following specimens of Pleistocene Cetacea. Probably there are others represented by scattered bones concerning which the author has not heard.

LIST OF KNOWN SPECIMENS OF PLEISTOCENE CETACEA FOUND IN NORTH AMERICA.

The dates given are those of the discovery of the specimens.

1849. A nearly complete skeleton, Charlotte, Vermont, Z. Thompson, in State Museum, Montpelier.

1858. Twenty vertebræ, mostly caudal, Sir J. W. Dawson, Geological Museum, Ottawa.

1864. A few detached bones, Riviere du Loup, Sir J. W. Dawson, Peter Redpath Museum, Montreal.

1870. A nearly complete skeleton, Cornwall, Ontario, Mr. E. Billings, Geological Museum, Ottawa.

1874. Considerable portion of a skeleton, Jacquet River, New Brunswick, Provincial Museum, Halifax, N. S.

1883. A few vertebræ and fragment of a rib, Smith's Falls, Ontario, Sir J. W. Dawson, Redpath Museum, Montreal.

1891. A part of the lower jaw, 11 feet, of a large whale, Metis, Quebec, Sir J. W. Dawson, Redpath Museum.

1895. A nearly complete skeleton, Smith's Brickyard, Papineau Road, Montreal, Sir J. W. Dawson, Redpath Museum.

1901. Ten vertebræ, ribs and parts of cranium, Smith's Brickyard, Montreal, Redpath Museum.

1901. A few bones, hyoid, etc., Williamstown, Ontario, Mr. E. Ardsley, Redpath Museum.

1906. Most of the skull and several vertebræ, Pakenham, Ontario, Dr. J. F. Whiteaves, in possession of finder.

In Bulletin 179, U. S. Geological Survey, Mr. O. P. Hay enumerates seventy-eight species of fossil cetacea. Of this number forty-three species are found in the Miocene, eleven in the Eocene, seventeen in the Tertiary, epoch not given, six in the Pleistocene and one which is not assigned to any epoch. Of the Pleistocene species, one, "a doubtful fossil," *Physeter macrocephalus,* was found in Louisiana. One is from South Carolina, *Physeter vetus,* one found in Vermont, *Delphinapterus vermontanus,* one from Alaska, *Monodon monoceros,* three from Canada, *Megaptera boops, Delphinap-*

terus leucas, Monodon monoceros, and possibly *D. vermontanus.* Three of the above species are still found in the Atlantic.

As some of the articles to which reference is made in the Bibliography are not generally accessible, the following notes respecting them will not be without value.

1. As will readily be understood, No. 1 refers to Professor Thompson's original description of the Vermont specimen. This is given in full in following pages.

2. A revision by Thompson of his first account. There are but few additions to what was first written.

3. This is substantially a reprint of No. 2.

4. This is little more than a passing allusion to the fossil, but is of interest because with the text there is a wood cut of the entire skeleton as it is mounted. The cut is not a good one in any respect, but as the first showing the whole specimen, and as one that has been copied in some of the leading works on geology, it cannot be passed without notice.

5. This refers to the following statement by Sir W. E. Logan:

"At the Mile-end quarries (Montreal), upon a slight ridge, are found stratified sand and gravel, holding boulders and shells in the lower part. The deposit sometimes rests directly upon the limestone rock, which is at other times covered with a thin layer of the boulder formation. The lower clay is here wanting, having perhaps been removed by denudation. A thick deposit of this clay is however seen at the brickyard of Messrs. Peel and Comte nearby, where it is overlaid by the Saxicava sand, and has furnished one of the pelvic bones of a seal, and several of the caudal vertebræ of a cetacean, *Beluga vermontana;* besides fragments of the white cedar, *Thuja occidentalis.*"

These bones are, as the above account states, all vertebræ, twenty in number. There are a few lumbar vertebræ, or what I take to be such, but most are caudal. The spines, neural arches and transverse processes are in general well preserved. As mounted with wooden disks in place of the intervertebral cartilages, the whole series is sixty-five inches in length. This specimen is in the Geological Museum at Ottawa.

6. In this, which is a Catalogue of Cetacea by E. D. Cope, the Vermont specimen is mentioned under the name given.

7. The reference here is to Scammon's Cetaceans of the west coast of North America, edited by Professor Cope.

8. In this reference Mr. Billings mentions the finding of bones of a whale as follows:

"Several months ago Mr. Charles Poole of Cornwall wrote to the Secretary of the Society that a large skeleton resembling that of an Icthyosaurus, had been found in that neighborhood, by the men engaged in excavating clay for brick. In another letter he stated that Mr. T. S. Scott, architect, of this city, had procured the lower jaws. On receipt of this information Mr. Billings called upon Mr. Scott, who very liberally presented the jaws to the Geological Museum. Mr. Billings then went up to Cornwall and obtained from Mr. Poole the bones which were in his possession. These were discovered in the Post-pliocene clay about sixteen feet below the surface. They are those of a small whale closely allied to the White Whale, *Beluga leucas,* which lives in the Northern seas, and at certain seasons abounds in the Gulf and lower parts of the St. Lawrence. The lower jaws are nearly perfect. The skull and upper jaws are much damaged and some of the parts lost. Thirty-five of the vertebræ, the two shoulder blades, most of the ribs, and a number of small bones were collected. The length of the animal was probably about fifteen feet. The lower jaws have the sockets of eight teeth upon the right side and of seven on the left. The number of teeth in the upper jaw could not be ascertained. In the head of a White Whale belonging to the cabinet of McGill College, there are nine teeth in the right lower jaw and eight in the left. The teeth of the fossil, judging from the size of the sockets, were longer than those of the White Whale."

For the above copy of Mr. Billings' account I am indebted to Dr. J. F. Whiteaves.

In this specimen the cranium is more complete than in any of the others that have been found. Measured in a straight line from the front of the rostrum, which is complete in the lower jaw, but not in the upper, to the lower part of the foramen, the length is twenty-one inches. The width across the base is nine and a half inches. There are no ear bones. The hyoid and one stylohyal are present. Mr. Billings in the account quoted mentions thirty-five vertebræ, but in the skeleton as mounted there are thirty-eight, viz.: 7 cervicals, 10 dorsals, 10 lumbars, 11 caudals and 1 chevron. In all of the vertebræ but four the spine is present and in all but two the neural arch. In all there is at least a part of the transverse processes. The bodies increase in length from the cervicals back to the tenth lumbar. In the third cervical, the first behind the axis, the body is a half inch long, while in the tenth lumbar the length is four and a fourth inches. The terminal caudals, probably not less than thirteen, are wanting.

The scapulas are particularly well preserved and are broken in different places, so that when taken together, the complete form can easily be made out. This is the usual form found in the dolphins. From the upper border in a straight line to the glenoid border they measure eight inches and it is ten inches across the upper border, while the coracoid processes are ten inches long on the upper side. Even these very long and slender processes are quite perfect. The humerus of the left side is wanting, but all the other arm bones of both sides are present.

There are ten ribs on the right side and nine on the left. These are more or less imperfect, but some are nearly whole. The longest, fifth, measures along the outer curve thirty-five inches. The whole skeleton is one hundred and forty-five inches long. The intervertebral cartilages are supplied by wooden disks.

9. In this notice Professor Cope briefly mentions that "Bones of a whale closely allied to the white whale, *Beluga leucas* of the Gulf of St. Lawrence have been discovered at Cornwall, Canada. It seems to be the same as the *Beluga vermontanus* of Thompson." This is obviously the specimen referred to by Mr. Billings.

10. This is really a monograph of European fossil cetacea and is of great value to students of this group. The full title is *Untersuchten ueber die Fossilen und Subfossilen Cetacea European.* It is an extensive paper accompanied by numerous plates. There is also a valuable discussion of the origin of some of the cetacean genera, but there is not much that has direct bearing upon American forms.

11. This refers to Dr. Gilpin's account of a fossil whale supposed to be the same specifically as the Vermont specimen. A full description of this specimen will be given later.

12. This is another notice of the Jacquet River specimen. A list of the marine shells found with the bones is given in the second reference.

13. This is simply a notice of several of the specimens of fossil whale which had been found and their probable identity with Thompson's species.

14. This is an article, "On portions of the skeleton of a Whale from gravel on the line of the Canada Pacific Railway, near Smith's Falls, Ontario," in which Dr. Dawson calls attention to the fact that "Bones of large whales are not of infrequent occurrence on the less elevated terraces of the Pleistocene period on the Lower St. Lawrence. The bones found on the lower, and therefore modern, terraces, are usually in a good state of preservation, and have a very recent appearance." Dr. Dawson then enumerates briefly several of the specimens of *Beluga* found in various localities and speaks particularly of some bones found in a ballast pit in gravel, thirty feet below the surface. "The bones secured consist of two vertebræ and a fragment of another with a portion of a rib, and others are stated to have been found. I have little doubt that they belong to the Humpback Whale."

In *The Canadian Ice Age,* p. 268, Dr. Dawson again notices these bones as follows: "*Megaptera longimana* Gray. Portions of a skeleton of this species have been found in 1882 in a ballast pit on the Canadian Pacific Railway, three miles north of Smith's Falls in Ontario, 31 miles north of the St. Lawrence River. They were imbedded in gravel along with shells of *Tellina groenlandica,* apparently on a beach of the Pleistocene period at an elevation of 440 feet above the sea, which corresponds nearly with one of the principal sea coast terraces on the Montreal mountain and other parts of the St. Lawrence valley. The specimens obtained were presented to the Peter Redpath Museum by Mr. A. Baker."

The bones above mentioned consist of two large vertebræ, a dorsal and a caudal and part of the neural arch of another dorsal and a part of a rib. The dorsal has a centrum ten inches in diameter and from tip to tip of the transverse processes it is thirty inches.

15. This is a well illustrated article by Professor Cope on "The Cetacea." One of the plates shows the entire skeleton of *Delphinapterus leucas.* In a "List of the Extinct Cetacea of North America," the Vermont specimen is included as *Delphinapterus vermontana.*

16. This is merely an allusion to the Vermont specimen with a copy of Thompson's figure of the cranium as it was found.

17. This refers to an account by Dr. Dawson of bones found in

"Leda Clays" near Montreal. The specimen is in the Redpath Museum, Montreal, and deserves more than a passing notice. It is one of the most complete of the fossil whale skeletons. Nearly all the bones are present and in good preservation.

Especially well preserved is the cranium, which is the most complete that I have seen, though, unfortunately, it lacks ear bones. The lower jaw is less perfect. There is a good hyoid, one entire and one fragmentary stylohyal, nine teeth of the upper jaw and two of the lower, both scapulas, all the arm bones, most of the sternum and thirty-six vertebræ. These are seven cervical, ten dorsal, ten lumbar, nine caudal. There are no phalanges and no chevrons. Most of these vertebræ are nearly or quite complete. All except two have the neural arch and spine, and all have at least a part of the transverse processes. The last few caudals are wanting. The ribs are in fairly good condition. Mounted without anything to supply the missing cartilages the length is one hundred and twelve inches, including the head.

18. This is simply mention of the Vermont specimen in Truessarts' list.

19. *Delphinapterus vermontana* Thomp. This is an account by Dr. J. F. Whiteaves of a series of bones of a whale as follows:

"On the fifth of September, 1906, a skeleton, which is obviously that of a very young individual of the white whale or *Beluga,* was found by Mr. Patrick Cannon while digging a well on his farm at Pakenham, Ont. This skeleton was imbedded in blue clay fourteen feet below the surface, and only a portion of it was dug out. In digging the well some depth of blue clay was first bored through, then a mixture of clay and shells in which the skeleton was found was struck and the excavation ended in blue clay.

"The bones that have been exhumed so far consist of a nearly perfect skull (with only a few of the teeth missing) and one of the tympanic bones with most of the cervical vertebræ and three of the dorsals with some of their epiphyses. Apart from their obvious immaturity, this Pakenham skull and the vertebræ immediately adjoining thereto, seem to be essentially similar to the corresponding parts of the skeleton of the *Beluga* from the Cornwall pleistocene, and that of a recent specimen of the White Whale from Metis in the Museum of the Survey."

In addition to the specimens mentioned there are in the Redpath Museum, Montreal, some bones of others which are worthy of attention. In the same clays that furnished the fine specimen mentioned above at Smith's brickyard near Montreal, there were found a number of bones, evidently from an immature animal. There are ten vertebræ, mostly caudal, with a few lumbars. The apophyses are wholly separate from the centra in all of these. They are apparently from a somewhat more than half grown animal. The largest has a centrum an inch and three-fourths in diameter. Besides these vertebræ there are five ribs or parts of them, and several parts of the cranium.

Mr. Edward Ardsley, Assistant Curator of the Redpath Museum, found at Williamstown, Ontario, a few bones, the hyoid, a few phalanges and fragments of ribs which are in the museum.

Both of these specimens seem to be of the same species as the complete skeleton, but specific identification is hardly possible where there is so little material.

DELPHINAPTERUS VERMONTANUS, Thompson.

The original description of this whale was published by Professor Z. Thompson in the *American Journal of Science,* 2d Series, Vol. IX, pp. 256–263, in 1850. The article bears the title, "An account of some Fossil Bones found in Vermont in making excavations for the Rutland and Burlington Railroad."

First, Professor Thompson says that "In grading the line of the Rutland and Burlington Railroad, portions of the skeletons of two large animals, both belonging to the class Mammalia and to families which no longer exist here in a living state, were found deeply buried in the earth, and the bones were for the most part in a very good state of preservation."

He then goes on to speak of the finding of several bones, both tusks, and a large tooth of a "Fossil Elephant" in a bed of muck in Mount Holly. After this comes the following:

FOSSIL CETACEAN.

"The fossil bones, which it is most particularly the object of this paper to describe, were found on the line of the Rutland and Burlington Railroad in the month of August, 1849, in the township of Charlotte, about twelve miles south of Burlington and a little more than one mile eastward from the shore of Lake Champlain. In widening a deep and extensive cut through stratified sand and clay, the workmen there struck upon a mass of bones. They were between eight and nine feet below the natural surface of the ground, and were very completely bedded in fine, adhesive blue clay.

"Little notice was taken of them at first until some of the overseers, thinking that they observed peculiarities in the form of several of the bones, were induced to commence an examination. They soon found that the bones discovered belonged to the anterior portion of the skeleton of some unknown animal, the head of which had already been broken into fragments by the workmen, and many of the fragments carried away with the earth which had been removed. On carefully removing more of the clay the vertebræ were found extending in a line obliquely into the bank and apparently arranged in the order in which they existed in the living animal. These vertebræ were, as was supposed, all taken out and together with the sternum, fragments of the head, ribs, etc., forwarded to Burlington, and by the kindness of Messrs. Jackson and Boardman, engineers on the railroad, were placed in my hands.

"Upon a careful examination of these bones I ascertained that the greater part of the head, all of the teeth and several vertebræ were wanting in order to complete the skeleton. To recover these, if possible, I immediately visited the locality, and at this and a subsequent visit I succeeded in obtaining most of the anterior portion of the head, nine of the teeth, and thirteen additional vertebræ, together with the bones of one forearm, several chevron bones, and portions of the ribs. My first object being to insure the preservation of the bones, I carefully cleansed them from the adhesive clay, and then saturated them with animal glue.

"When I first looked at the bones I was in doubt whether they belonged to an animal of the cetaceous or saurian family, but my doubt was soon removed by a careful examination of the caudal vertebræ. These I found to have their articulating surfaces convex and rounded in such a manner as to allow of very extensive certical motion of the tail, and but very little lateral motion.

"This circumstance plainly indicated that the movements of the animal in the water were effected by means of a horizontal caudal fin and that it, therefore, belonged to the family of cetacea."

Reference is then made to figures of three vertebræ, showing the mode of articulation.

"But if there had still remained any doubt with regard to the general character of the animal, it would have been entirely removed when I succeeded in reconstructing afterwards out of the fragments of bones which I procured, so much of the anterior portion of the head as to exhibit distinctly its spiracles, or blow holes, showing unequivocally that it belonged to the whale family. My next object was to ascertain, if possible, whether it belonged to an extinct or to a living species or genus of this family. By a careful examination of Cuvier's great work on fossil bones, I became satisfied that in the osteology of the head it bore a strong resemblance to a small Arctic cetacean called *Beluga* or White Whale, *Delpinus leucas* (Cuv. Oss. Foss. v. p. 297, pl. xxii, fig. 5 and 6, Paris ed., 1825), and that it therefore belonged to the living rather than to the extinct types, and this opinion was confirmed by Professor Agassiz, to whose unrivalled skill and kind assistance in the investigation of these fossils I am deeply indebted.

"The head of the skeleton, as already remarked, was broken into a great number of pieces, but enough of these have been recovered and matched to determine very nearly the form and entire length of the head and of one side of the lower jaw, and of its symphysis with the other side.

Figure 1.

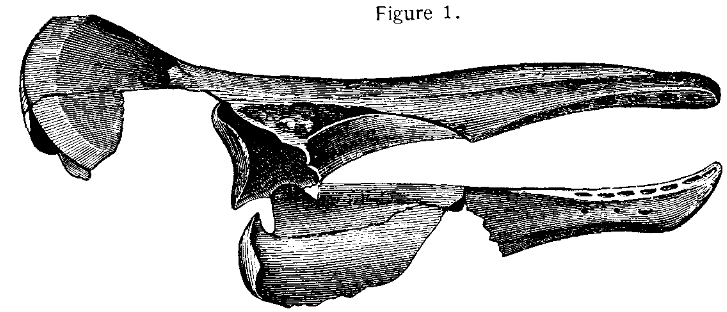


Fig. 1, copied from Thompson, shows the appearance of the cranium of Delphinapterus vermontanus as it was found, one sixth natural size.

"The fragments of the anterior portion of the upper jaw were found and matched, with the exception of so much of the maxillary bone as formed the alveolar margin of the left side. The alveolar margin of the right side measures 6.85 inches in length and contains eight alveoli. In the corresponding side of the lower jaw there are seven alveoli in a length of 5.5 inches, the alveolar margin extending three inches farther backward, but not perforated for teeth.

"It appears from what has been said above that the animal had seven teeth in the lower jaw and eight in the upper, on each side, making thirty teeth in all. Of the vertebræ I secured forty-one, of which four are cervical, eleven dorsal, ten lumbar and sixteen caudal. Three of the cervical vertebræ, the first, fifth and sixth, are evidently wanting, which with those obtained would make seven, the usual number. These vertebræ are all free, not being soldered together as in the common dolphin and some other cetaceans.

"Of the dorsal vertebræ, the second and twelfth are missing, making the whole number thirteen.

"Two of the lumbar vertebræ, the sixth and twelfth, are missing, making twelve in the whole. They all have the same general form, but the lateral winged processes are more decayed and broken in some of them than in the one represented (the seventh).

"The eleventh and seventeenth caudal vertebræ are missing, and perhaps a nineteenth and twentieth, making their probable whole number twenty. From these statements it appears that the whole number of vertebræ in the skeleton was fifty-two. Eleven of these are missing, two of which are known to have been taken away when they were dug up, and may perhaps be recovered. Articulating surfaces on the under sides of the caudal vertebræ indicate five chevron bones, of which I have all but one, only the fourth being gone.

"The total length of the vertebral column, allowance being made for the eleven missing vertebræ, but none for the intervetebral cartilages, is just ten feet, or one hundred and twenty inches. Of this length the cervical vertebræ occupy eight inches, the dorsal thirty-six, the lumbar forty-two, and the caudal thirty-four.

"The lumbar vertebræ are largest, having an average length of about four inches and a diameter of three inches. The total length of the animal, including the head and caudal fin, must have been at least thirteen feet. The hyoid bone and the sternum are both very large and strong in proportion to the size of the skeleton. The former measures eight and a half inches in a straight line from point to point, and the latter is fifteen inches long, three to seven wide and on an average one inch thick. There are four articulating cavities for ribs on each side. The ribs are considerably decayed and much

broken. The longest rib in one piece measures just twenty-four inches along the curve. The ribs which form the anterior pair are very strong and unbroken and consist one each side of two parts of solid bone.

"Of the limbs, the two scapulæ, one humerus, and the two arm bones on one side, and the ulna of the other side are secured; all the other bones of the fins are missing.

"The length of the humerus is five and of the forearm four inches. There are several of the recovered bones whose places are yet to be ascertained. Some of these may be appendages to the hyoid bone, and others may belong to a rudimentary pelvis. Professor Agassiz, who has manifested, as already stated, a deep interest in these fossils, has kindly consented to give them that further careful investigation and illustration which their importance demands, and for which he is most ably qualified. I have, therefore, placed them in his hands for that purpose." . . . (Then follow comparative measurements of the fossil specimen and those given by Cuvier for *Delphinapterus leucas.*)

"From these measurements it might be inferred that the fossil and *D. leucas* were identical in species as well as genus; but at the same time, so many points of disagreement have been observed as to render it highly probable that they are specifically different. In the number of teeth they differ. They also differ much in the relative width of the maxillary and intermaxillary bones, as developed on the upper side of the snout. . . . The lines of the face appear also to be straighter, and the coronal process less elevated, making the upper portion of the head flatter in the fossil than in *D. leucas.* That this fossil cetacean belongs to the genus *Delphinus* of Linneus and to Lacepede's subgenus *Delphinapterus,* I have little doubt; but, as already stated, it is highly probable that it belongs to a different species from Gmelin's *leucas.* I would therefore propose *Delphinus vermontanus* for its provisional specific name, until its identity with *D. leucas* or some other known species shall be established.

"The locality where these fossil bones were found is situated a little more than a mile to the eastward of Lake Champlain and 60 feet above the mean level of the lake, as ascertained by the railroad survey. The mean height of the lake is 90 feet above the level of the sea, making the height of the point where the fossils were imbedded 150 feet above the sea. The geological formation in which they were found is very clearly characterized. It belongs to that portion of the Post-tertiary which has sometimes been denominated the Pleistocene formation. This formation extends along the whole length of Lake Champlain and throughout the valley of the St. Lawrence. On the east side of the lake in Vermont it frequently attains a width of several miles, and in places exceeds 100 feet in depth. It consists for the most part of regularly stratified sand and clay resting upon the Champlain rocks or upon unstratified drift and portions of it abound in marine bivalve shells. These shells are of several species, nearly or quite all of which are now found in a living state on the Atlantic shores of New England and it is common to find them with the valves united, with their epidermis undisturbed, and buried in such a manner as to show unequivocally that they lived, propagated, and died in the places in which they are found. The most abundant species is the *Sanguinolaria fusca; Mya arenaria, Saxicava rugosa,* and *Mytillus edulis* are quite common. Some other species are occasionally found.

"The cut for the railroad, in which these fossil bones were obtained, is nearly half a mile in length, extending from north to south, and its greatest depth is eighteen feet. The depth of the cut where the skeleton was found is ten feet. About four feet of this depth, reckoning from the natural surface of the ground, consists of sand, showing no signs of stratification. Next below this is a mixture of sand and clay, which is regularly and distinctly stratified for a depth of two and a half feet, below which is a vast bed of blue clay in which I observed no sign of stratification, and which appears to have been, previous to the deposit of sand and clay above it, a kind of quagmire.

"In the lower part of the stratified sand and clay and nearly in contact with the upper surface of the blue clay were the fossil bones. The highest part of the skeleton was about eighteen inches below the upper surface of the blue clay, or eight feet below the natural surface of the ground. In the clay mingled with the bones I found a number of specimens of *Saxicava rugosa* and two of those of *Nucula,* and I also found in it such indications of vegetable remains as to leave little doubt that this clay bed once, and for a long time constituted a salt marsh, with rushes and grasses on the shore of the Pleistocene sea that then occupied the valley of Lake Champlain."

In the Appendix to "Thompson's Vermont," which was published three years later than the above, Professor Thompson adds further notes which are quoted later.

As will be noticed, Thompson uses the generic name *Delphinus* in his original description, although he states that the specimen belongs to the subgenus *Delphinapterus,* and *Beluga* in the later one.

Other than the above account by Professor Thompson no detailed description of this skeleton has been published and, with the exception of a few of the wood cuts which accompany Thompson's article, no satisfactory illustrations. The separate bones were collected and mounted many years ago for exhibition in the State Museum. It is very regrettable that while this work was done with evident care and much labor, it is yet very faulty from an anatomical point of view. It is the hope of the writer that it may be taken apart and more accurately put together, but the difficulty of doing this has caused him to let it stand for the present as it is. Some of the lacking vertebræ and other bones have been replaced by very well shaped wooden models, but as seen in its case, nearly all of the skeleton is genuine. It is eleven feet and seven inches long as mounted, the intervertebral cartilages not being supplied and most of the bones are in very good condition.

Most unfortunately the vertebræ are many of them reversed and the bones of the head not all accurately adjusted. Writing in 1860, Mr. A. D. Hager, then curator of the museum, says concerning this: "It may be proper to remark that the bones of the head were so much broken by the workmen who encountered it that but an imperfect idea of its shape could be obtained from the preserved fragments by one not familiar with comparative anatomy. The outline of the head, therefore, may not be true to nature, but the writer, acting in the capacity of curator, concluded that an artificial head, embracing the bones that had been preserved, if attached to the skeleton, even if it were not a perfect model of the original, would be more attractive to visitors than the remaining portion of the skeleton would be without a head. Hence he fitted it up, not to elicit the criticism of the learned zoölogist, but to render the skeleton more interesting to the casual observer."

This is all well as far as the intentions of the curator were concerned, but while for the purpose in mind it was excellently done, it was unfortunately for comparative anatomy so well done that it would now be, I judge, quite impossible to make it over as it should be.

It may perhaps be noticed here that, while the accompanying illustrations are presented with considerable hesitation on account of the inaccuracies just mentioned, it has been impossible to remount the specimen at present, if indeed it can be done at all without serious damage to the bones, the old mountings having become firmly fixed in place. On the whole, the writer has thought best to give the figures which show the specimen as it has been for fifty years and let them pass for what they are worth. Plate x, upper figure, shows the entire skeleton reduced to about one fourteenth its full size.

THE CRANIUM. From what has just been said of this part of the specimen it will readily be seen that a minute description is not of much value. Its present appearance is well shown by Plate xi and Plate xii, which was taken especially to show the cervical vertebræ and the base of the skull. The parts that have been wired, that is most of the front portion, are genuine, the work of restoration is mainly confined to the occipital region in which bones and plaster are a good deal mixed. By reference to Figure 1 what has been added may be better determined. It is very fortunate, considering the conditions when the bones were found, that anything of the cranium was preserved.

Thompson says of the cranium as it was soon after it was found: "The entire length of the head is twenty-one inches. The maxillary bone on the left side is mostly wanting, but on the right side it is entire, so far as to embrace the alveolar margin, which is six and eighty-five hundredths inches in length and perforated for eight teeth. The corresponding alveolar margin of the lower jaw measures five and a half inches and is perforated for seven teeth.

"Hence it appears that there were sixteen teeth in the upper jaw and fourteen in the lower, making thirty in the whole. The teeth are all of one kind, being conical with flat or rounded crowns, much worn, but their substance very dense and firm. They are from one to two inches in length with a diameter of half an inch. Only nine of the teeth were recovered, and none of these were in their places when found, but that they were in their places up to the time the bones were discovered is evident from the fact that while every other cavity in the bones was filled with clay, the alveoli were empty."

Plates xi and xii show well the top and right side of the cranium and those parts that are restorations are fairly distinct. The principal portions that had to be added to the parts found are the middle of the lower jaw between the alveolar portion and the condyle. This is shown in Plate xi, and it will be noticed that at least three-fourths

of the mandible is the original. On the upper part of the cranium some vacancies have been filled. This necessitated the completion of the occipital crest, on one side, though not much. The nasals, upper parts of the intermaxillaries, the superior maxillaries and a few others have more or less added to complete the original in its broken condition. In length the cranium as set up agrees with that given by Thompson when he first received it. It is 21 inches (55.5 centimeters).

THE LOWER JAW. As may be seen in the plate, the posterior portion of the lower jaw is artificial. It is, however, very well shaped, though not properly articulated with the cranium. Its length is 17.5 inches (42.5 centimeters).

THE TEETH. There are thirty alveoli in all, but only nine teeth were found. Their condition plainly indicates that the animal was fully adult, as the upper ends are much worn. Several are seen in position in Plate xi, and two given full size on Plate xiii.

As shown, they have the usual form found in this group of the cetacea. The larger is 1.3 inches (3.3 cent.) long and not quite half as much in diameter. The other is a little less.

THE PERIOTIC. It is rather strange that Thompson in his detailed account of the finding and identifying of these bones should not have mentioned the ear bone. I have not, however, found any allusion to it in any of Thompson's writings. The only one that remains with the skeleton is the right periotic. The bone is, as noticed later, very small for such an animal, but as only this one individual specimen has been found in the state it must have belonged to it. The bone has the usual irregular and somewhat peculiar shape found in all cetacean ear bones and is more easily described by the figures on Plate xvi than by words. It is shown natural size, its greatest length being 1.6 inches (39 mm.) and height 1.13 inches (29 mm.). The portion of the bone which was found with the skeleton is very well preserved. Additional remarks concerning this will be found in what follows.

THE HYOID BONE. Professor Flower says that "The ossified portion of the hyoid in the true Dolphins consists of a large subcylindrical, slightly curved stylohyal on each side, and a flattened crescentic median bone, composed of the anchylosed basihyal and thyrohyals." *Osteology of the Mammalia,* p. 190. If this is the condition in *Delphinaptera,* then what we have shown in Plate xiii is this compound bone made up of thyrohyals and basihyals. It appears to be large and heavy for the size of the skeleton. As the plate shows its general outline is roughly, very broadly A shaped or triangular. The sutures between the thyrohyals and the basihyal is distinct, but the anchylosis is complete. The width, measured across the ends of the thyrohals, is 8.5 inches (21.25 cent.). Distance from the end of each thyrohyal to the top of the basihyal, 1.6 inch (15 cent.); length of each thyrohyal in a straight line is 4 inch (10 cent.). One is a little longer than the other, the difference probably being due to some crumbling of the end in the shorter one, though this may not be so, for it is smaller in all its dimensions. At the suture with the basihyal the breadth of each thyrohyal is 1.65 inch (4.2 cent.), and at the lower end 1 inch (2.5 cent.); thickness where greatest, at end near the basihyal, .9 inch (2.3 cent.); at the other end .5 inch (1.2 cent.). The basihyal is subquadrangular in outline. The width across the top is 2.25 inches (6.7 cent.), across the lower edge 1.75 inches (4.4 cent.). Plate xiii shows this bone two-thirds full size as seen looking on the upper side. The whole is very well preserved.

The stylohyals in allied species are stout and of large size and they were so probably in the present specimen, but I cannot find any trace of them among the bones at Montpelier, so that we must conclude that they were not rescued when the bones were collected.

The Vertebral Column. Plate x. As the number of vertebræ in different species of the cetacea varies considerably, it is uncertain how many there were in our specimen when living. Forty-one were found, but it is certain that these are not all. According to Thompson: "Three cervical vertebræ, the first, fifth and sixth, are evidently missing. . . . The second and twelfth dorsal vertebræ are missing. . . . The lumber vertebræ amount to twelve, of which the sixth and twelfth are missing. . . . The eleventh and seventeenth caudal vertebræ are missing and perhaps a nineteenth and twentieth. . . . From these statements it will be seen that the whole number of vertebræ in the skeleton was fifty-two, eleven of which are missing."

As set up in the museum there are fifty vertebræ, of which number nine have been replaced by wooden ones. The probable number of each kind of vertebræ was seven cervical, thirteen dorsal, twelve lumbar and nineteen or twenty caudal. The length of the column as set up is nine feet ten inches, or a little more than three meters.

Cervical Vertebrae. Plate x, upper figure, also in part Plate xii. As has been noted the atlas was not found. The axis is therefore first in the mounted skeleton, as the missing atlas was not supplied. The large relative size of the axis is seen in Plate xii, where it is best shown. The individual vertebræ would have been detached temporarily for illustration, but I found that this could not be safely done, the wiring had been so thorough. As the illustration shows, this vertebra is triangular, narrow in proportion to its size. It is 6.5 inches (16.25 cent.) wide across the lower side and 4.6 (11.6 cent.) high to top of spine. The spine is 1.25 inches wide and 2 inches across the body. The rest of the cervicals are very narrow. There are, as noticed, four original and two of wood, the sixth and seventh. The vertebræ are all distinct and there is no evidence that any of them were anchylased, as is common in some of the cetacea.

Dorsal Vertebrae. Plate x, middle figure. According to Thompson there should be thirteen dorsal vertebræ. Most of these were found, only the second and twelfth being lost. Plate x, middle figure, shows the first eleven and the lower figure on Plate x shows the last two. In all the neural spine is more or less injured and in most so much so that the neural arch is incomplete, as is well seen in the figure last referred to. Indeed, the arch is entire only in the seventh dorsal, though nearly so in the second, third and sixth. In all the rest it is broken so that it has no upper portion, as is best seen in the last two.

As stated, Thompson says that the twelfth dorsal is lacking and the appearance of the column as set up confirms this, for the transition between the dorsal and lumbars should be slight as in all cetacea.

Lumbar Vertebrae. Plate x, lower figure. The complete number of lumbar vertebræ is twelve. Of these ten were found. Two have been replaced. All are shown on Plate x, about one-fourth natural size. In the middle figure the column was turned sidewise to show the transverse processes better. Most of these are considerably broken, but some are nearly complete, as in the fifth, seventh, eighth and ninth. The sixth is of wood. The lumbars do not increase very greatly from the first to the end, though of course the last are larger.

The first measures as follows: Body 3.25 inches (8.3 cent.) long, 2.12 inches (5.3 cent.) wide, 7 inches (17.7 cent.) across the transverse processes, and from this the increase is gradual till in the twelfth we have the following: Length, 4.5 inches (11.4 cent.) vertical diameter, 4.25 inches (10.8 cent.), width across the transverse processes, 10 inches (25.5 cent.). The transverse processes are thin, spatulate when complete, which none of them is, but by comparing one with another the entire form may be restored. The third from the posterior end of the figure is artificial. The figure shows two dorsals and seven lumbar, but all the latter were mounted in a reversed position, as were the three shown at the right end of the lower figure. The transverse processes are all too much broken to be accurately measured, but the longest was probably 4 inches (10 cent.) long.

CAUDAL VERTEBRAE. In the cetacea, as there is no sacrum, the division between the lumbars and caudals is not easily made out. If we take as a guide the presence of chevrons, then, allowing twelve lumbars, there should be nineteen, or as Thompson suggests, twenty caudals. The first eight of these are shown in the lower figure on Plate x. Here again the vertebræ have been reversed, so that the front as seen is really the posterior end. The remaining caudals which were obtained are seen in the figure of the whole skeleton on the same plate. As will be noticed, the neural spines are wanting in all the dorsal and in those caudal vertebræ which had them.

CHEVRONS. Five of the chevron bones were saved. Four of these are plainly seen in the lower figure of Plate x. The other was accidently pushed up in moving the skeleton and its displacement not noticed till after the photograph was taken. It may be seen in with the neural canal between two of the vertebræ. These bones do not present any special characters differing from allied cetaceans. The vertebræ shown in the two lower figures of Plate x are about one-third natural size.

THE STERNUM. Plate xv. The sternum or breast bone is a massive and large bone, well shown in the plate. As this shows, it is very much wider across the upper border than at the opposite one. The dimensions are as follows: Extreme length, 14.75 inches (42 cent.); width across upper edge, 6.5 inches, near the lower edge, 3.5 inches (8.9 cent.), and about 1 inch (2.5 cent.) thick, though the thickness varies of course at different points.

THE RIBS. These bones have suffered more from decay than any other part of the skeleton. What of the thirteen pairs were found are shown in Plate xv. Of these there are nine pairs more

or less complete, and there are also a number of fragments which cannot be fitted to the skeleton with any reasonable accuracy and therefore have not been attached to it. I should think that all the parts of ribs taken together would represent nearly the whole, though in a fragmentary condition. There is some doubt whether the rib seen in the plate in position as first is really first or second. It is hardly as stout as the first in allied species and yet is not certainly different. It is either the first or second and whichever it is, the other is wanting. Moreover, in the thorax, as seen in Plate xiv, the rib which is now placed second in the skeleton should undoubtedly be put farther back and the broader rib placed behind it should come forward as third. The rib placed first in the skeleton as seen in the plate is shorter and wider than any of the others, as it should be. Following the outside curve it is 19.75 inches (54.7 cent.) long. The width at the point where the two parts are wired is 2 inches (5 cent.). The longest rib, which may be the fifth or sixth, is 24 inches (61 cent.) around the outside curve.

THE ARM. This is well shown in Plate xiv, although here the humerus, ulna and radius are wooden models of the real bones, which are on the left side of the skeleton and do not show in any of the photographs. The models are very exact copies of the bones they represent, yet all the following account is taken from the bones of the left arm, as they were fortunately secured when the skeleton was unearthed.

As the plate shows, the scapula is a good deal broken about the edges, so that its precise outline cannot be obtained.

It may be noticed that Thompson says that the scapula and ulna of the right side were the only bones of the anterior limbs that were recovered. Other bones must have been recovered later, for in the specimen as mounted all the bones of the left side are present.

THE SCAPULA. In the cetacea most nearly allied to the Vermont species this bone is broad and more or less fan-shaped. Accordingly we may suppose this to be true in our specimen, although the bones do not seem to have as regular an outline as those of many of the cetacea.

THE HUMERUS is short and thick with large globular head. The lower end is much flatter and less thick. The length of the humerus is 4.5 inches (11.5 cent.). It is 8.25 inches around the head and 6.5 inches around the lower end.

THE ULNA AND RADIUS. These are also very short and thick, as shown in the plate. The ulna is 3.75 inches (9.5 cent.) long, width at upper end, 1.75 inches; at lower end, 2.4 inches; across upper end, 1.75 inches. The radius is less flat and more round. It is 3.25 inches (8.3 cent.) long, 1.5 inches wide at the top and 2 inches at the lower end.

No digits were found.

Is the Vermont specimen *Delphinaptera vermontana* or *leucas?*

As seen from the list given in the bibliography, most authors have accepted Thompson's reference of his specimen to a new species, so far as the use of the name he proposed is concerned, but when we examine the text of many of the articles we find doubts often expressed as to the validity of the species, most of those who have considered the matter concluding that the Vermont specimen does not differ in any essential respect from the *D. leucas* still living in the Gulf of St. Lawrence and elsewhere.

Professor Thompson gives his reasons for placing the specimen in a new species as follows: After giving a series of measurements of *vermontana* and *leucas* he says:

"Between these measurements it will be seen that there is a very close agreement, but they disagree in their dental formulæ as expressed below:

	B. vermontana.	*B. leucas.*
Dental formula	$\frac{8}{7}\ \frac{8}{7}=30.$	$\frac{9}{9}\ \frac{9}{9}=36.$

"They also differ in the relative width of the maxillary and intermaxillary ones, as developed on the upper side of the head. Since the above measurements and comparisons were made I have had an opportunity to examine the bones of three heads of *B. leucas* in the Hunterian Museum in London and an entire skeleton of the animal in the collection of Professor Agassiz at Cambridge, Mass. On account of the absence of Professor Agassiz when I visited Cambridge a minute comparison of my fossil bones with the corresponding ones of his skeleton was not gone into, but a sufficient number of bones was compared to leave little doubt that they belong to different species of the same genus. I have therefore described my *Beluga* under the specific name *vermontana,* which I gave it provisionally in my first account of the fossil." (Appendix, Thompson's Vermont, p. 18.)

Some years later, after the discovery of several more or less complete skeletons in Canada, Mr. Billings and Dr. J. W. Dawson concluded that the Canadian specimens were identical with the living *D. leucas* and also with Thompson's *D. vermontana.* From this it necessarily follows that Thompson's species should not stand. Neither of these gentlemen, however, appear to have seen the specimen found by Thompson and they formed their opinions solely on the not very satisfactory figures published by Thompson. Mr. Billings writes that he compared the bones of the nearly complete skeleton found in Cornwall with those of a recent skeleton of *D. leucas* and concluded that the two were the same species, and according to Dr. Dawson, "extended this conclusion to Mr. Thompson's specimen," the distinctive characters of which as stated by that author seem not to exceed the individual differences in modern specimens.

In Canadian Ice Age, page 268, Dr. Dawson says "there seems no good reason to believe that the *B. vermontana* of Thompson from the Pleistocene of Vermont is distinct from *B. catodon* (*leucas*)."

Dr. Whiteaves in a personal letter which he kindly allows me to use, is more cautious. In this he writes: "The identification of the Mile-end specimen and of that from Cornwall with *Beluga vermontana,* it must be remembered, is solely on the authority of the late Mr. E. Billings. It seems to me that the specimens from these two localities and the skull, etc., from Pakenham (which are all that I have seen) are at any rate all referable to the same species. And I do not see how they are to be distinguished from the recent *D. leucas.* If then Billings was correct in referring the Mile-end and Cornwall specimens to *Beluga vermontana* (which perhaps remains to be seen), it looks as though *B. vermontana* may be only a synonym of *D. leucas.*"

Dr. True says as to this, in a personal letter to Dr. Whiteaves: "I feel considerable hesitancy in pronouncing on the validity of Thompson's species, as I have never seen the type specimen, and Thompson's description and figures are far from satisfactory, though excellent for the time in which they were published. If his characters are taken literally the inference would be that the species is quite distinct from *D. leucas.* For example, the vertebral formula of *D. vermontana* is C. 7, D. 13, L. 12, C. 20=52. The formula of *D. leucas* is C. 7, D. 11, L. 9, Ca. 23=50. Although all species of dolphins vary much in their formulæ, there is no such amount of variation as is shown in the two formulæ cited. If the differences noted actually existed there would be a strong probability that *D. vermontana* was distinct. As a matter of fact, however, Thompson did not have all the vertebræ and he may or may not have been mistaken in calculating the number lost. I should want to see the specimen before forming an opinion on that point."

In order to decide so far as possible this and several other questions that had arisen in course of my study of the Montpelier skeleton, I took photographs of the entire skeleton and larger ones of the different parts to the American Museum of Natural History, New York. Here there are numerous cetacean skeletons, mounted and disarticulated. By the courtesy of Mr. Roy C. Andrews I was not only able to use this material freely and most helpfully but, what has been of much further assistance, Mr. Andrews freely gave me all aid in his power, and to this and to his experience as special student of the cetacea I am greatly indebted. Doctor Tower, librarian of the museum, also gave valuable aid in finding books to which I had reference. Mr. Andrews called my attention to numerous points in the anatomy of the group which else had been overlooked.

Naturally, the most important question was that first discussed, that is, whether the Vermont specimen possesses sufficient differences from *Delphinapterus leucas* to confirm Thompson's name *vermontana*. That the generic status of the specimen is correctly determined, that is, that it is a true *Delphinapterus,* there is, I think, no doubt, but whether it is identical with the living species *leucas* or should be placed as a new species, as Thompson thought, is not so readily decided, as those who are familiar with the skeletons of cetacea will readily understand. The individual variation is so great in most parts of the skeleton and the resemblance of some of the bones of different species and even of different genera makes specific determination often a difficult task. For this reason, determination of species by comparison of bones with not over perfect wood cuts is not likely to secure the best results.

A comparison of the fossil bones with recent skeletons shows some differences not thus far noted. The end of the snout appears in the fossil to be more blunt and to end more squarely. The scapulas also appear to have been of different form from those of the recent specimens, but the fossil scapulas are so imperfect that one cannot decide with certainty as to their original form. Still, I think

that enough of the fossil bones remains to indicate a form unlike that of the corresponding bones in *D. leucas.* Doctor True has spoken in his letter of the difference in the axis. This bone does not appear to be much, if any, broken and if this is true, it certainly is unlike that of *leucas.*

As to the difference in dentition of which Thompson speaks, Mr. Andrews writes, "The dentition of the cetacea is by no means as constant as in other mammals. In all the *Delphinidae* the teeth are open to more or less individual variation, both in size and number."

After returning from New York I found in the case with the bones a periotic. This I at once sent to Mr. Andrews for examination. Perhaps no bone in the skeleton of the *Delphinidae* is more constant in its specific characters than this, hence its importance.

After receiving this bone Mr. Andrews wrote as follows: "I have compared the bone with the ear bones of several specimens of *Delphinapterus leucas.* The resemblance except in point of size is very close indeed. The bullate portion of the periotic in your specimen is somewhat smaller in proportion to the total length of the bone than in *D. leucas.* The internal auditory meatus is also slightly different in shape. However, I believe that these characters are open to a slight individual variation. The difference in size seems to be an important one as it probably indicates that your specimen, if adult, is a smaller animal than *D. leucas.*

"A comparison with the periotic of a very young individual of *D. leucas* shows this bone in the latter individual to be considerably larger than in your specimen. The bone itself agrees so closely with other specimens of *Delphinapterus* in general characteristics that there can be no doubt of its identity with that genus."

As to the question of age which is raised it may be said that there can be no doubt from the teeth and from the sutures of the head that our specimen was fully adult.

After twice visiting the New York museum and studying the cetacean skeletons there the writer went to the National Museum at Washington for the same purpose. Here Doctor True was most obliging and helpful. As has been stated a set of photographs of the Vermont specimen had already been taken at the request of the National Museum and these were in Doctor True's possession. Since then I have received a letter from Doctor True from which I quote the following paragraphs:

"The periotic of *D. vermontanus* appears to indicate that the species is distinct from *leucas*. The principal differences are that in the periotic of the former the petrosal is larger, the porus acusticus internus also large and differently shaped, the posterior process of the petrous body much longer and more pointed, the anterior process more rounded, the fenestra cochleae larger.

"I cannot see that the vertebræ of *vermontanus* present any tangible differences of importance. The neural arch of the axis appears to be differently shaped, but this is probably due to its imperfect condition. The vertical foramina in the sides of the centra of the caudals appear smaller, but there is considerable variation in this character. The coracoid process of the scapula is narrower at the end, but this is also variable. I think the ulna is straighter. It is really necessary in identifying such material to examine the specimens themselves."

Learning that the bones found on the Jacquet River in New Brunswick were in the Provincial Museum at Halifax, I wrote to the curator for information concerning them. As a result of this correspondence the curator of the museum, Mr. Harry Piers, very kindly sent me the bones in possession of the museum, thus giving me the best possible opportunity to compare them with the Vermont specimen. The bones were not articulated and some are badly broken, but as a whole they are in a very good condition. The reference in the bibliography, number 11, is the account of the Halifax specimen.

The original statement in the Transactions of the N. S. Inst. Natural Science, Vol. III, p. 400, is as follows:

The article is entitled *"Observations on Some Fossil Bones Found in New Brunswick, Dominion of Canada,"* by J. Bernard Gilpin, Md. M. R. C. S.

The portions of a cetacean skeleton here described appear to be more numerous than those of any other find of the sort except that in Vermont. The statement is as follows:

"These bones were taken from one of the cuttings of the Intercolonial Railway on the Jacquet River, Bay de Chaleurs, New Brunswick. After cutting through sand and gravel for about twelve feet a bed of clay was reached. In this the bones were bedded."

Then follows a list of ten species of fossils shells, three of which also occur in the Vermont clays. The account continues:

"The cutting is forty feet above the level of the sea, and one fourth of a mile from it, and on the north side of the river. . . . The clay is Post-pliocene and of the Lake Champlain period. . . . The fossil bones consist of eighteen vertebræ, a small portion of the atlas, about twelve fragments so thick and so marked by nearly obsolete sutures as to prove them portions of the base of the skull, the petrous portion of one ear, about one half of the lower jaw, a fragment of the sternum, fragments of both scapulas, one humerus, radius, ulna and phalanx, one or two ribs, numerous fragments of ribs, and spinous processes of vertebræ. They are entirely free of animal matter, of a light fawn color and so dry or chalky as to leave a dusty mark on everything they touched. From comparison with some of the recent bones in the Halifax museum of some of the smaller recent cetaceans and with the plates of the bones of the Boston whale (*B. musculus*) by Doctor Dwight, Boston N. H. Society, there can be no doubt but that they are the remains of some ancient small cetacean inhabiting the Champlain clay period."

"Of the eighteen vertebræ, four are dorsal, ten lumbar and four caudal. The four dorsal are all more or less incomplete in the neural arch and transverse processes. The largest one measures in its centrum or body, two and three fourths inches in transverse section of articulating surface and two inches in length.

"The height of the neural arch is one inch and three quarters, and two and one half breadth of the floor of the arch. The spinous processes are all incomplete. . . . Of the fourteen (vertebræ) remaining ten may be considered lumbar. The largest measures four inches long and three inches transverse diameter. . . . A fragment of the sternum remains, nine inches long, irregularly triangular, and having on its left side very deep marks of its articulation with the ribs. It is slightly convex on its external surface and slightly concave on its internal and was evidently much longer.

"The fragments of both scapulas remain. . . . From the fragments it seemed that they resembled pole axes, the head being the cavity for the humerus. The humerus is very complete, with the head large, the shaft short and thick and the muscular marks and processes very bold. . . . Its length is four and one half inches and breadth at the head two and a half. A very perfect radius, broad and flat, . . . length four inches, breadth one inch and a half, a fragment, barely enough to show it to have been the ulna, its olecranon gone, and one small phalanx completed the bones of the upper extremity.

Of the very numerous fragments of the ribs, but two or three remain so entire as to show their original shape. Their articulating surfaces, both vertebral and sternal, are large . . . and, while one of the shortest, or sternal, measures nine inches, the largest or abdominal, with a very flattened extremity, measures two feet.

"The fragment of the lower jaw so exactly resembles the cut in Dana's Geology of *Beluga vermontana* as to hazard the conjecture that they are closely allied if not identical."

This was written in 1873. Since that time some of the bones appear to have been lost, for among the twenty-three separate bones sent by Mr. Piers there are, as the following account shows, no examples of ribs or limb bones, no jaw bone nor, except one or two fragments, no cranial bones. The bones sent are as follows: Two fragments of the basioccipital, two much broken scapulas, the periotic, sternum, four dorsal vertebræ, five lumbar and eight caudal. As will be shown later, the specimen has the characters of *Monodon* rather than of *Delphinapterus*. If this is so there should be in all seven cervicals, eleven dorsals, six lumbars and twenty-six caudals, or fifty in all. There are therefore thirty-three vertebræ lacking.

All these bones are more chalky and brittle than those of the Vermont specimen. The different bones which are complete enough to warrant particular description are the following:

The Periotic. Plate xx. The left periotic is present and is all that is preserved of the ear bones. Fortunately, it is in excellent condition. It has the usual irregular form of this bone, and this can be better understood by an examination of the plate than from any verbal description. It is shown slightly larger than natural size. As has been noticed, no other bones of the head have been seen by the writer except two thick fragments of what appears to be the Basioccipital, but these are too small to be of much value.

The Vertebrae. All that have been preserved are shown in Plate xvii, except one, which should come last in the figured series. This was accidentally omitted when the photographs were taken. They have been arranged as nearly as possible in natural order, but it is to be remembered that more than half of the original column is lacking and therefore there are several vertebræ which immediately follow each other in the plate but which originally were separated by intervening bones. A glance at the plate is sufficient to show the imperfect condition of all the bones, especially as to the processes.

In only one is the spine even partially seen, except in the last few caudals, where its changed form enabled it to withstand the vicissitudes through which the bones had passed. The neural arch is seen in but two, the first and third, and the transverse processes are seen more or less broken in nine, though they are badly injured in all but five or six. As might be expected, the bodies of most are in very good condition. Naturally the last caudals are pretty nearly whole.

The Dorsal Vertebrae. As none of the cervical vertebræ were saved, the first of this series are dorsal. These are the first four of Plate xvii. The first, on Plate xvii, is undoubtedly one of the anterior vertebræ of the dorsal series, but it does not seem to be the first. The neural arch is complete, though the transverse processes are largely gone. Plate xviii, upper figure, shows this vertebræ on a larger scale, being reduced to one third natural size. In the actual specimen, the body is 2⅜ inches (60 mm.) wide and 2 inches (52 mm.) high. It is 2 9-16 inches (65 mm.) long. The under side of the body in this and more in the three that follow is not rounded, but bears a distinct carinæ, especially in the middle of its length. At the ends it is more rounded. The neural canal is larger in this than in any succeeding vertebræ. Measured in front it is 1⅞ inches (48 mm.) high and 2⅞ inches (73 mm.) wide. Both ends of the body are nearly flat, the posterior being a little concave. It may be here noticed that all the measurements given of different vertebræ the largest dimensions are taken. The following three dorsals are, I judge, from the latter part of the series. In form they resemble the lumbars that come after them. Especially is this true of the form of the lower side and of the body. Thus there appear to be several—probably four or five—vertebræ wanting between the first in the photographed series and the second.

The second dorsal as seen in the figure is probably the sixth or seventh in the full series. As the figure shows the neural arch is nearly gone, but the left transverse process is much better than it is in most others. The body is distinctly heavier than in number one. Anteriorly its dimensions are: Width, 2½ inches (65 mm.); height, 2 5-16 inches (59 mm.); neural canal, 2⅝ inches (67 mm.) wide.

The transverse process is stout, much thickened at the end, flat above, rounded below. It is 3 inches (76 mm.) long, 3¼ inches (32 mm.) wide next the body and 2 inches (51 mm.) wide at the outer end. Here it is 1 inch (25 mm.) thick. The body of this vertebra is 2 13-16 inches (72 mm.) long.

Number three of the figure, which I suppose to be about the eighth dorsal, is somewhat more complete than the other dorsals. The neural arch is entire and both transverse processes are in good condition, as the figures on plates xvii and xviii show. The body of this vertebra is, anteriorly, 2⅜ inches (60 mm.) high, 2¾ inches (70 mm.) wide and 3 inches (76 mm.) long. The neural canal is 7 7-16 inches (37 mm.) high and 2¼ inches (57 mm.) wide. The left transverse process is 3⅝ inches (92 mm.) long. The last dorsal in the series is probably the tenth or eleventh, as it has most of the characters of a lumbar, but has, as the lower figure of Plate xviii shows, the articulation for the ribs on each transverse process. Anteriorly the body measures 2 7-16 inches (62 mm.) in height, 2¾ inches (70 mm.) in width and is 3¼ inches (83 mm.) long. The transverse process of the left side is in excellent condition and measures 4¾ inches (121 mm.) in length.

The third figure from the top in Plate xix shows a good typical cetacean lumbar and probably is not far from its proper position, that is, it may be the third or fourth in the actual lumbar series. In this the body is 2¾ inches (70 mm.) high, 2 13-16 inches (72 mm.) wide and 3½ inches (9 mm.) long. The left transverse process is more nearly whole than any other of the lumbars. It is somewhat broken at the end and is thin and flat. As it is, it is 4½ inches (114 mm.) long and 2⅜ inches wide at the end.

Lumbar Vertebrae. Without the presence of chevron bones it is often very difficult to determine the end of the lumbars and the beginning of the caudals, but probably the first bone of the last series in Plate xvii is the first caudal. If this is true, then there are five lumbars present. Even in their broken condition, the difference in the transverse processes is evident. Other changes not obvious in the figures are the lengthened bodies and increased vertical diameter. All have a well-marked inferior carina, but this is also well seen in the last dorsals. The first of this series appears to belong among the first four or five, probably it is the fourth.

The centrum is 2⅝ inches (68 mm.) high, 2¾ inches (71 mm.) wide, 3½ inches (85 mm.) long. As in all the lumbars the transverse processes are quite unlike those of the dorsal vertebræ. They are thin, flat, come from the body at a lower point and are wider. All are so broken that it is not possible to measure them with exactness, or even to be sure as to the original form. The third bone

from the top in Plate xix is most perfect of all the lumbars. The left transverse process is nearly complete in this bone. The bone was probably the third or fourth in the actual series.

Its measurements are: Height of centrum, 2⅞ inches (73 mm.); width, 2 13-16 inches (71 mm.); length, 3½ inches (87 mm.). The tranverse process 44½ inches (114 mm.) long and 2⅜ inches wide at the end. The length was slightly greater before the end was broken.

The remaining lumbars do not offer any features of especial interest. That which appears to be the last, in Plate xix, shows the increasing circular form of the centrum as towards the caudals and the width of the neural canal is only a little more than its height.

Caudal Vertebrae.—The eight vertebræ which represent the caudal series, as Plate xvii indicates, differ from the anterior portion of the series to the end. This is seen by comparing the first and last of the lower series.

If there were originally, as I suppose, twenty-six caudals, then eighteen must be lacking. Apparently there are several vertebræ lacking between the third and fourth, lower series, Plate xvii, as the transition is too great to indicate consecutive bones. The rest are lacking at the end.

In the fourth the body is larger than in any other of the entire series. The spine is very different from those in preceding vertebræ. It is not only lower and relatively wider, but is furnished with blunt, rounded metapophyses, as may be seen in the next vertebra, Plate xix. The centrum in the fourth is 3½ inches (83 mm.) high, 3¼ inches (83 mm.) wide and 3¾ inches (95 mm.) long. The neural canal is greatly reduced, having here a width of only ⅜ inch (10 mm.), or one seventh of that in the first vertebra. The transverse processes are reduced to mere ridges along the sides of the body and a little farther back they disappear. There is also a backward projection which in following vertebræ becomes a horizontal spine. In these last vertebræ the centrum becomes nearly circular.

All the button or disk-shaped caudals found at the end of the series in the cetacea are missing. Apparently there should be at least twelve posterior to the last one shown in Plate x. It has been noticed that in arranging for the picture the photographer accidentally left out the last caudal in Plate xvii, but it is shown in the lower right hand of Plate xix and back of this there should be ten or twelve more.

As of the twenty-six caudals normally found in *Monodon* there are only eight present in this specimen, there must be in all eighteen lacking. If twelve of these would come after that shown at the end of Plate xvii, then there would be six lacking in front of the first of this last series.

No chevron bones were found with the rest of the skeleton.

In the figure of the skeleton of *Monodon* in Van Beneden and Gervais, *Osteographie des Cetaces,* Plate XLIV, there are fourteen of these bones shown. All the vertebræ shown in Plate xvii are reduced to about one fifth of the full size.

The following list of measurements of the different vertebræ may not be without interest to comparative anatomists. All measurements of the neural canal and diameter of the centrum, or body, were taken in front.

Measurements of Vertebræ of Halifax Whale.

	No.	Length of Body.	Width of Body.	Height of Body.	Width of Neural Canal.
Dorsal.	a	65 mm.	60 mm.	52 mm.	73 mm.
	b	72 mm.	70 mm.	60 mm.	70 mm.
	c	76 mm.	70 mm.	61 mm.	57 mm.
	d	82 mm.	70 mm.	65 mm.	48 mm.
Lumbar.	e	85 mm.	71 mm.	68 mm.	48 mm.
	f	87 mm.	71 mm.	69 mm.	43 mm.
	g	90 mm.	73 mm.	73 mm.	40 mm.
	h	90 mm.	75 mm.	74 mm.	37 mm.
	i	93 mm.	76 mm.	75 mm.	35 mm.
Caudal.	j	93 mm.	78 mm.	76 mm.	32 mm.
	k	93 mm.	81 mm.	77 mm.	25 mm.
	l	94 mm.	83 mm.	77 mm.	22 mm.
	m	95 mm.	87 mm.	80 mm.	10 mm.
	n	69 mm.	85 mm.	83 mm.	10 mm.
	o	66 mm.	77 mm.	83 mm.	8 mm.
	p	56 mm.	65 mm.	70 mm.	5 mm.
	q	49 mm.	62 mm.	70 mm.	4 mm.

When laid in consecutive series, as in Plate xvii, the vertebræ measures 55 inches (137 centimeters) in length. Of course this does not include any intervertebral cartillages, which would add appreciably to the total length of the spinal column.

As far as I have been able to determine by study of skeletons of recent specimens, the total length of the Halifax specimen when living must have been not far from twelve feet, and this corresponds very well with the size of living *Monodons,* to which genus, as will be shown later, this specimen is referred. Specimens of living *Monodon monoceros* that have been taken are from ten to fourteen feet long, so that the Halifax specimen is of about average size.

The variation in form of the centrum in different vertebræ is well seen by comparing different figures of Plates xviii and xix, which give the width as compared with the height in the dorsals and the almost circular form found in lumbar, and the still more entirely circular outline of the centrum in the caudals.

Still, the centrum is wider than high in all vertebræ before the eighth. After this the height grows a little greater than the width.

The length of each centrum or body increases from the first to the thirteenth. From here it decreases to the end.

The neural canal is largest in the first. Here it is broadly oval, much wider than high. In the third, which, as before stated, is probably the eighth dorsal and the only other vertebra in which both width and height can be measured, the width is reduced to 57 mm. and the height from 73 mm. to 38 mm., and, as the figures in the table of measurements show, it goes on diminishing until in the last of this series, which is probably about the fourteenth caudal, it is only 4 mm. wide.

The Sternum.—As Plate xx shows, this bone is thick and large. It elements are completely united so that no trace of suture can be found.

Although the bone is considerably broken, yet enough remains to show pretty nearly its original form. This is less distinctly triangular than in many of the cetacea. As the plate shows, the upper part of the left side and the lower part of the right are nearly whole.

Articular surfaces for three ribs are plainly shown, but those of the other three, there being normally six ribs connected with the sternum in *Monodon,* are wanting.

Exact measurements cannot in all cases be given because of the broken condition of the bone, but the following are nearly correct: Length, 9 inches (229 mm.); width across the upper end, 7½ inches (191 mm.); width across the lower end at the articulations, 3¼ inches (83 mm.). The thickness at the top is 1½ inches (38 mm.). The general thickness is on the average rather more than ¾ inch.

Longitudinally the bone is only slightly curved and the surfaces are, as a whole, nearly flat.

Plate xx shows the sternum, four ninths natural size.

THE SCAPULA.—Parts of both scapulas are among the bones saved. They are thin, fragile and badly broken. Hence their original form cannot be definitely ascertained. They appear to be unusually thin and small for an animal of such size. A considerable part of the glenoid cavity is intact and this part of the bone is heavier and more solid than the rest. Each is about 2¼ inches (57 mm.) in diameter vertically.

SPECIFIC POSITION OF THE HALIFAX WHALE.

In Doctor Gilpin's description of this specimen we find the following: "The fragment of the lower jaw so exactly resembles the cut in Dana's Geology of *Beluga vermontana* as to hazard the conjecture that they are closely allied if not identical." Students of this group do not need to be told that this is a wholly valueless identification. And yet, since Doctor Gilpin's account, his suggestion that his specimen was of the same species as Thompson's Vermont specimen has been allowed to pass without a word of dissent, so far as I can find. After the Halifax bones had been sent by the kindness of Mr. Piers, curator of the museum, they were taken to Montpelier and compared with those there. It needed only the briefest examination to show important points of difference, and had the Canadian specimen been as complete as the Vermont, it is probable that the differences would have appeared even greater.

Very fortunately in both specimens the periotic, which for specific identification is most important, was present. An examination of Plates xvi and xx will indicate how dissimilar are these bones. So also there are differences in other bones. It is not necessary to go into an extended comparison of the two skeletons here. It must be sufficient to call attention to a few of the most evident and important points.

Taking up the periotics as more important than any other of the bones, we may note the remarkable differences to which attention has already been called as they appear in Plates xvi and xx. In this case it is possible to quote the opinions of Doctor True of the U. S. National Museum, who is, I suppose, the peer of anyone in America as an authority on the cetacea, and Mr. Andrews of the American Museum, who is also a special student of the group and one of the best authorities.

At the time of my consultation with Doctor True, I was unable to show him the actual bone, but after studying a series of photographs of the bone, he wrote as follows:

"As regards the Nova Scotia specimen, I think there is no doubt that it is not *Delphinapterus,* on account of the shape of the periotic and the short lumbar vertebræ. Our skulls of *Monodon,* unfortunately, are without the periotics so that I cannot make comparisons of importance, but Van Beneden and Gervais' figures indicate a shape similar to that shown in your photographs. None of the latter, however, are from the same point of view as the figure."

Mr. Andrews had the bone itself and reported:

"I have just finished a comparison of the periotic bone which you sent with that of *Delphinapterus leucas* and of *Monodon monoceros.* As soon as I looked at the periotic of this specimen it seemed to me that it resembled very closely the corresponding bone of *Monodon.* A comparison shows that in size and general shape it agrees very much better with *M. monoceros* than with *D. leucas,* in fact the whole shape of the bone is decidedly unlike *Delphinapterus.*

"In order to verify my opinion I showed the specimen to Dr. W. D. Matthews and he agreed with me that, while there are some points of difference between the periotic of this specimen and that of *Monodon,* yet it is certainly closer to that genus than to *Delphinapterus.*

"Your specimen, on the other hand, agrees well with *Delphinapterus,* consequently it would seem to me unlikely that it and the Halifax whale can be of the same species or even the same genus. The tympanic and periotic are, so far as I am aware, subject to less individual variation than any other bones in the cetacean skeleton and the remarkable difference shown in the Halifax whale would seem to me good grounds for a pretty close investigation of the species if it has been referred to *Delphinapterus.* Of course, if you could see the rostrum of the Halifax specimen and determine whether or not the upper teeth were present, it would simplify matters very greatly, for *Monodon* has no teeth aside from the tusk."

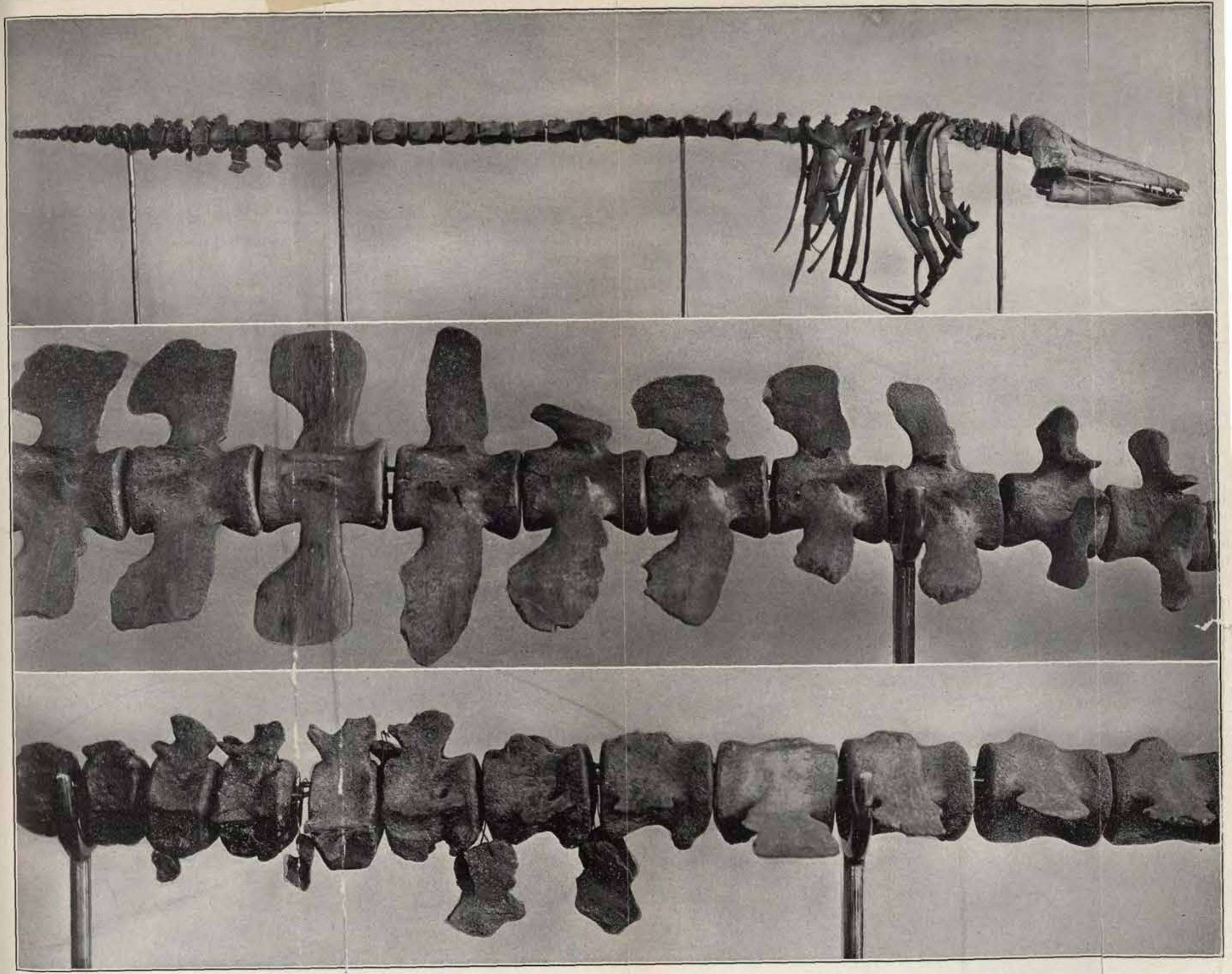
Very much to my regret, I was unable to submit any of the bones of the Halifax specimen to so eminent an authority on cetacea as Dr. F. W. True. I was able at a later time to compare photographs of this specimen with the very fine skeletons of *Monodon* in the New York Museum. As a result of all this it seems quite certain not only that the Halifax specimen is not *Delphinapterus,* but that it is *Monodon.* It is doubtful whether it can be determined with entire satisfaction whether it is identical with the living *M. monoceros* or a closely allied extinct species.

Authorities recognize but one living species of *Monodon* and this has been several times found as far south as England, though its habitat is given as Arctic seas. Nicholson and Lyddeker, *Manual of Paleontology,* page 1307, says that: "Remains of Narwhal, *Monodon monoceros,* are in the Norfolk forest beds and the Pleistocene of Alaska." In Transactions of the Zoölogical Society, London, 1866, Professor Flower proposed the group *Belugineæ* to include *Delphinapterus* and *Monodon.*

OTHER CANADIAN SPECIMENS.

All the other Canadian specimens that have been found, so far as I know, are enumerated in the list on page 79.

Whether these are to be referred, as they have been, to Thompson's *D. vermontana* or *D. leucas* can hardly be quite fully determined. In some cases, the bones that have been found are not such as to make definite specific identification possible. So far as they are concerned the specimen might be either of the above species.

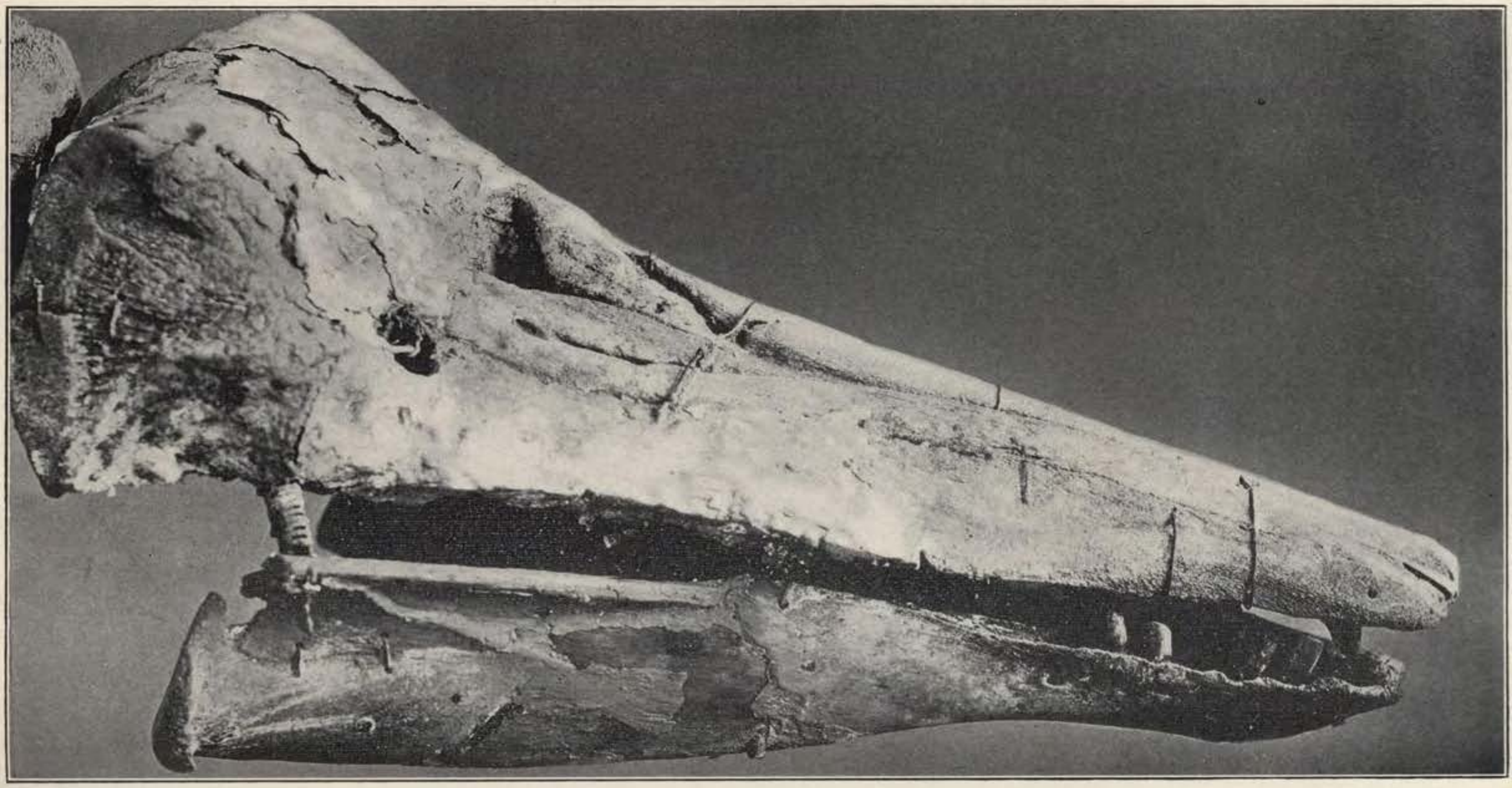


UPPER FIGURE.— Entire skeleton of *Delphinapterus vermontanus,* Thompson, as mounted in the State collection, Montpelier. About one-thirteenth natural size.

MIDDLE FIGURE.—*Two Dorsal and Eight Lumbar Vertebræ.* The vertebræ back of the support are turned to show the transverse processes. These are all reversed, the anterior face being turned backward. The sixth lumbar is artificial. One-third natural size.

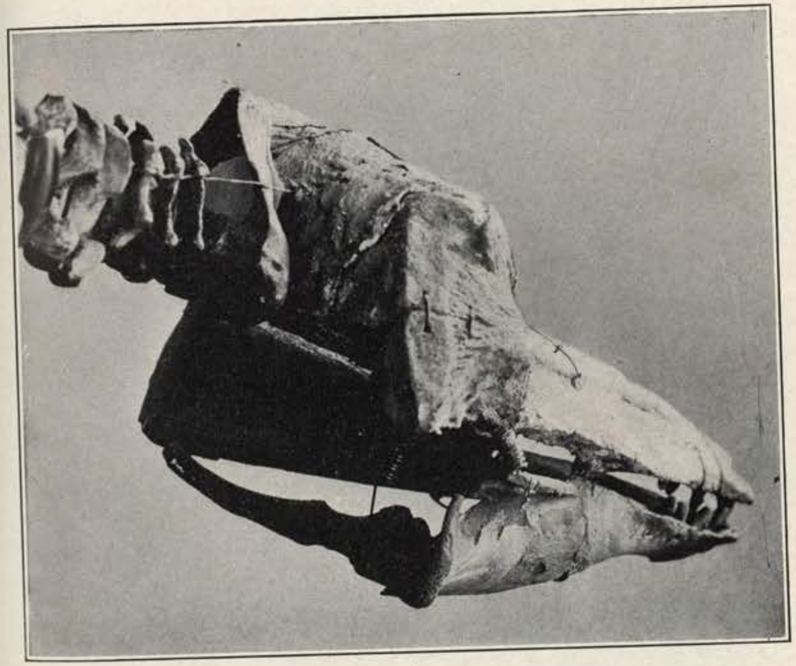
LOWER FIGURE.—*Last Lumbar and first Caudal Vertebræ.* These too, were reversed in mounting. Five chevrons are shown, one being thrown up between two spines. One-third natural size.

PLATE XI.



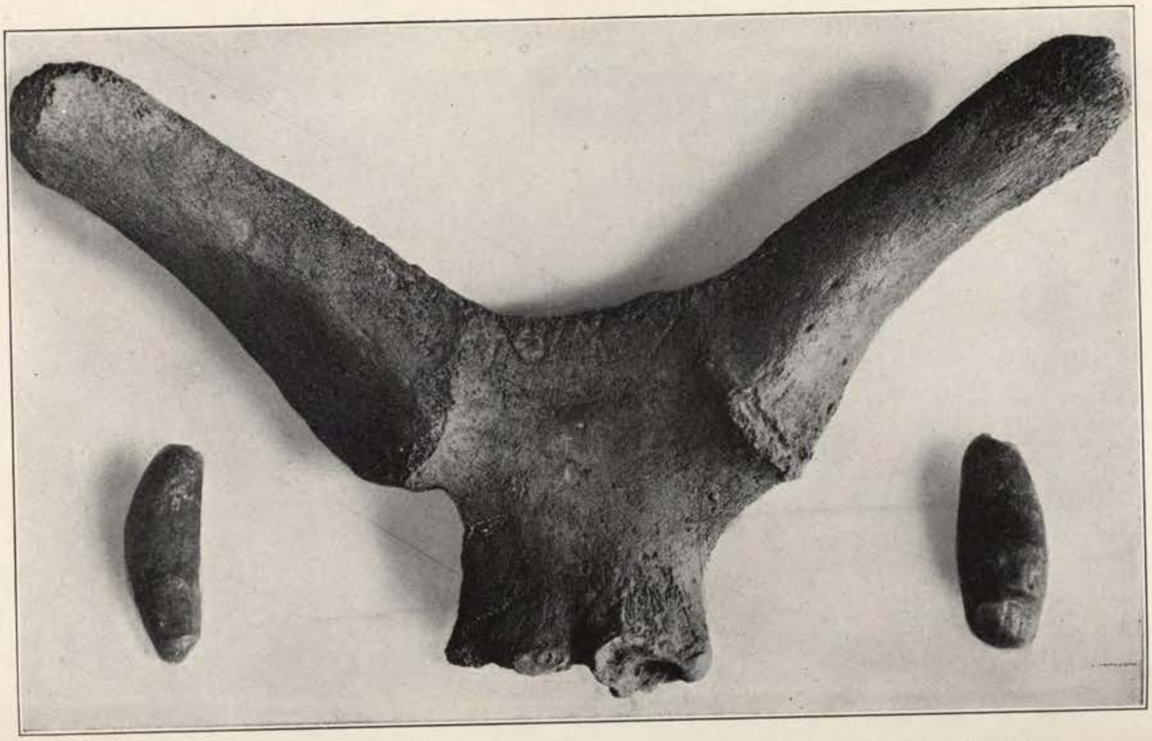
Delphinapterus vermontanus, Thompson. Cranium reduced to one-third natural size.

PLATE XII.



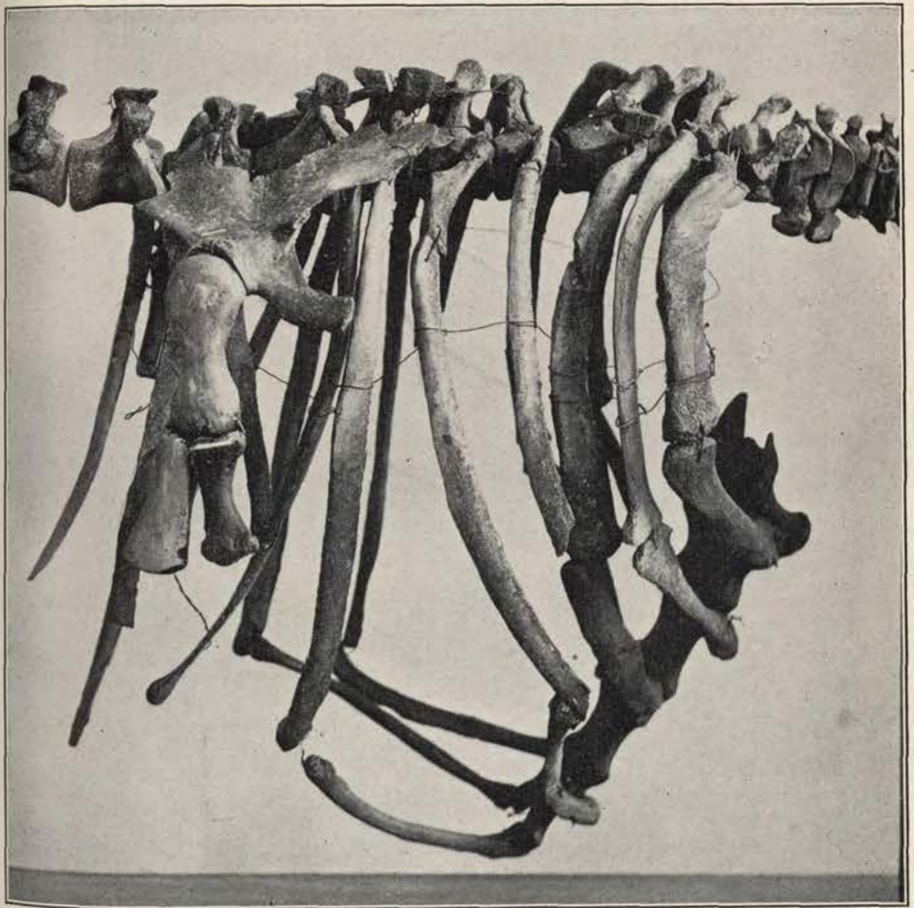
Delphinapterus vermontanus, Thompson. Turned obliquely to show axis, hyoid, etc. Cranium and cervical vertebræ, one-seventh natural size.

Plate XIII.



Delphinapterus vermontanus, Thompson. Hyoid, two-thirds natural size. Two lower teeth, natural size.

PLATE XIV.



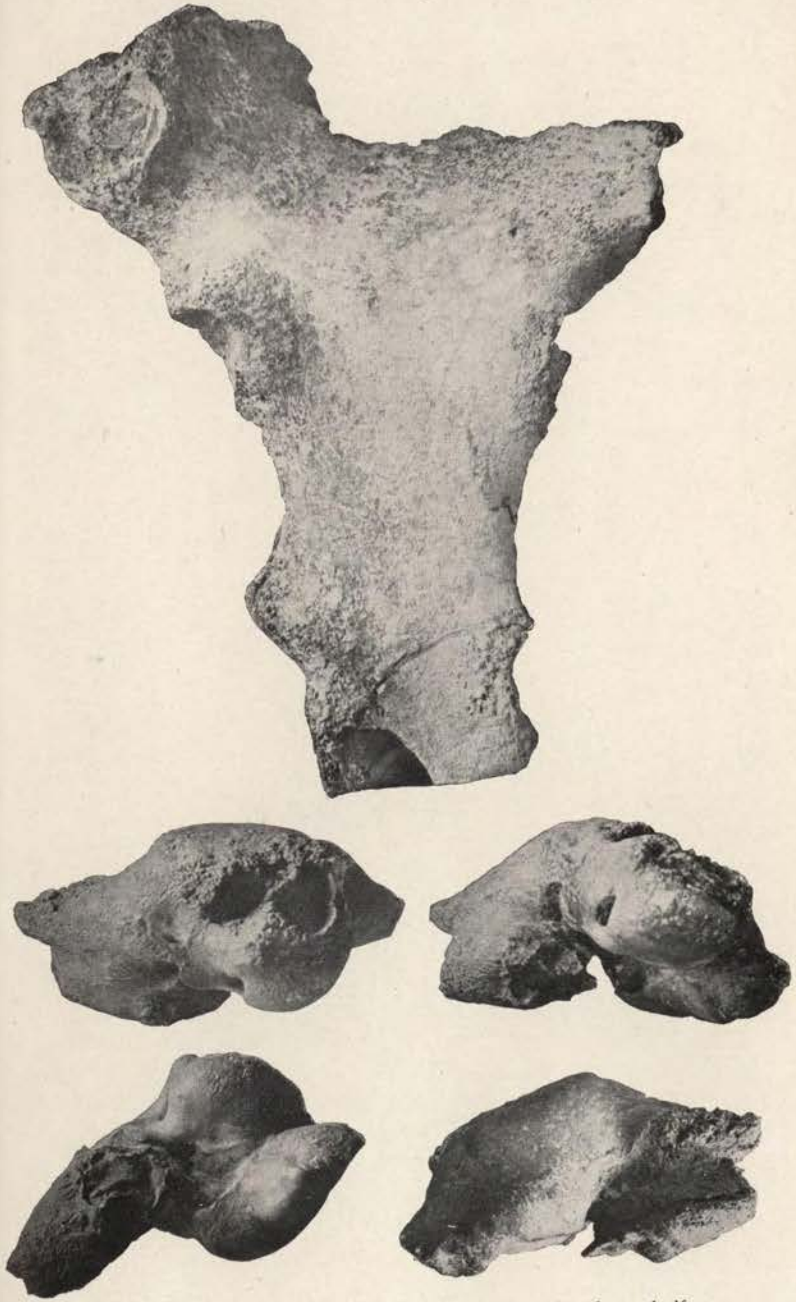
Delphinapterus vermontanus, Thompson   Anterior part of skeleton.   About one-seventh natural size.

PLATE XVI.

Delphinapterus, Periotic.

PLATE XVIII.

Monodon. Dorsal Vertebræ. One-third natural size.



Monodon Sternum and Periotic. Sternum reduced one-half.

Some late Wisconsin and Post-Wisconsin Shore-lines of North-western Vermont.

HERBERT E. MERWIN.

CONTENTS.

INTRODUCTION.

The investigation upon which this paper is based was made during the summer of 1906. The work was done as J. D. Whitney Scholar for 1906, under the direction of Professor Woodworth, to whom I am indebted for many suggestions, especially as to field methods and interpretations. The field expenses were paid by Harvard University from the Josiah Dwight Whitney fund for geological field study. Mr. Harold C. Durrell of Cambridge, Mass., accompanied me at his own expense during most of the summer, very graciously assisting me in many ways.

The district studied includes chiefly that portion of Vermont which lies north of the middle of the state, and west of the divide between

Lake Champlain and the Connecticut River. The work was extended to Shefford Mountain and Brome Mountain in southern Quebec.

The chief rocks of this district are metamorphic. The dominant structures, belts of gneiss, schist and limestone, strike N. N. E. After the surface of these rocks had been maturely dissected, it was glaciated and, along the western part, depressed below sea-level, and partly buried by marine and fresh-water deposits which are largely of glacial origin. In many of the valleys further east there are large bodies of water-laid glacial materials. Changes of local water-levels during the retreat of the ice-front, and successive elevations of the region (of which the area under consideration is a part) have led to a considerable dissection of the deposits just mentioned.

In describing in more detail those parts of Vermont and Quebec with which we are concerned, it is convenient to divide the area on a topographic basis into an eastern highland, which includes part of the Green Mountain Highland; and a western lowland, which includes the southern part of what may be called the Champlain Lowland (Plate xxi, figure a).

THE HIGHLAND.—The highest parts of the main ridge of the Green Mountains are in the highland part of the area. Several points on the ridge are over 4,000 feet in altitude. Mt. Mansfield, which occupies a central position in the area studied, rises 4,364 feet above the sea. Through this ridge and lower ridges on the east and west, the three largest west-flowing rivers of Vermont have cut deep water-gaps. The depth to which these gorges were cut before they were partly filled with glacial materials is not precisely known, for the glacial materials have not yet been sufficiently removed or explored. South of Mt. Mansfield where the Winooski River has cut through the ridge, the gravelly stream bed is less than 330 feet above the sea. North of this mountain the bed of the Lamoille River is scarcely 150 feet higher.

Several of the longitudinal subsequent valleys east of the main ridge are but little higher than the water-gaps through which they are drained. For example, the valley next east of Mt. Mansfield, the northern part of which drains to the Lamoille River, and the southern part to the Winooski River, is only 740 feet in altitude at the divide on the floor of the valley, between these streams.

The northern ends of some of the longitudinal valleys northeast of the one just described drain northward from similar low divides into Lake Memphremagog, thence into the St. Lawrence River; some of the valleys southeast drain southward through branches of the White River, into the Connecticut River.

THE LOWLAND.—The lowland part of the area studied is bounded on the east by the high ridge of the Green Mountains, and on the west by the Adirondack Mountains; at the south it narrows and merges into lowlands of a similar character in the middle Hudson valley; at the north it is continuous with the thousands of square miles of almost dead level clay plains south of the St. Lawrence River. Above the plains in Quebec several igneous stocks rise. Brome Mountain and Shefford Mountain are two such stocks situated about 25 miles north of Vermont. Below the level of the plains there is an area extending the entire length of northwestern Vermont which was not completely filled to the general level by glacial deposits. This area is occupied by Lake Champlain. The surface of the lake is 96 feet above the sea, according to Gannett's (1906) dictionary of altitudes.

THE SHORE-LINES.

PROBLEMS STATED.—The problems in mind when this study was begun may be stated as follows:

1. What evidences are there of abandoned Pleistocene shore-lines on the eastern side of the Lake Champlain drainage basin?

2. Are such shore-line features as may be found associated with local bodies of water, or may they be correlated with shore-lines already made out in the western part of the Champlain district?

3. Did any of the Pleistocene lakes which once occupied valleys now draining westward into Lake Champlain drain eastward into the Connecticut River?

PREVIOUS STUDIES.—C. H. Hitchcock and others ('61, p. 93-191) early mapped and described many terraces and so-called shore-lines of northwestern Vermont. Later, Baldwin ('94) studied some of the evidences of submergence along the eastern shore of Lake Champlain, and Chalmers ('98, p. 12-19) makes reference to beaches in southeastern Quebec. Woodworth (1905) has brought together the results of his own observations and those of others in the Lake Champlain district. I give here a summary of the history of the body of water which occupied the valley of Lake Champlain during the retreat of the Wisconsin ice-sheet, as such history has been sketched by Woodworth.

While the southern end of the ice-tongue which occupied the Champlain valley stood in the vicinity of the present divide between the Champlain and Hudson valleys, a body of fresh water known as Lake Albany bordered the ice-tongue and drained southward. At a later time the waters of the southern part of Lake Albany were drained away, but the waters of the northern part were held in at a lower level than the original level by a barrier across the basin near Schuylerville, N. Y. This smaller lake has been called Lake Vermont, or Glacial Lake Champlain, for from this beginning it continued to extend northward across Vermont in the Champlain valley as the ice-front retreated. The highest level of this lake was determined by an outlet just east of Quaker Springs, N. Y. This stage of Lake Vermont, Woodworth (according to a verbal statement to the writer) would now call the Upper Coveville stage. A rather gradual lowering of this lake took place until an outlet near Coveville, N. Y., at a level 100 feet lower, inaugurated a period of nearly constant level, known as the Coveville stage. The ice-front now stood somewhere between Port Kent and Street Road, N. Y.[1] (opposite the southern third of the Vermont area which is under consideration).

After the lake stood for some time at this level, during which time the ice-front was continuing to retreat, another outlet, through the valley of Wood Creek, took the drainage of the lake and lowered the lake-level another 100 feet. This is the lowest outlet which has been discovered for Lake Vermont. The probabilities are that the subsequent lowering of the lake-level was caused by the leaking out of water toward the north, around or beneath the ice. When the ice no longer formed a barrier across the northern end of the Champlain valley the sea had free access to the present site of Lake Champlain, owing to the fact that the land was depressed at the north. The amount of depression at the site of the present foot of Lake Champlain was about 450 feet. This depression was of the nature of a tilting, for the head of Lake Champlain was not then below sea-level. Since the sea first came into the valley there has been uplifting at the north so that the shore-lines developed at that marine stage are now inclined toward the south at the rate of about 3.65 feet per mile.[2] This tilted plane is the upper marine limit.

All the shore-lines made at the different stages of Lake Vermont participated in this upwarping, so they also slope southward.

[1] Woodworth, 1905, p. 196.

[2] This figure was obtained from calculation based on the profile, Plate 28, of Woodworth's report (1905, p. 226).

PRELIMINARY DATA.—*Determination of Altitudes.* Altitudes were determined by means of the aneroid barometer and hand level, using such reference points as could be found in Gannett's (1906) Dictionary of altitudes, and on the Burlington and Middlebury topographic sheets.

Glacial Striae.—Some idea of the final movements of the glacial ice in the valleys, as a clue to the position of possible ice barriers as parts of shore-lines, seemed highly desirable. For this reason glacial striae were mapped whenever encountered.

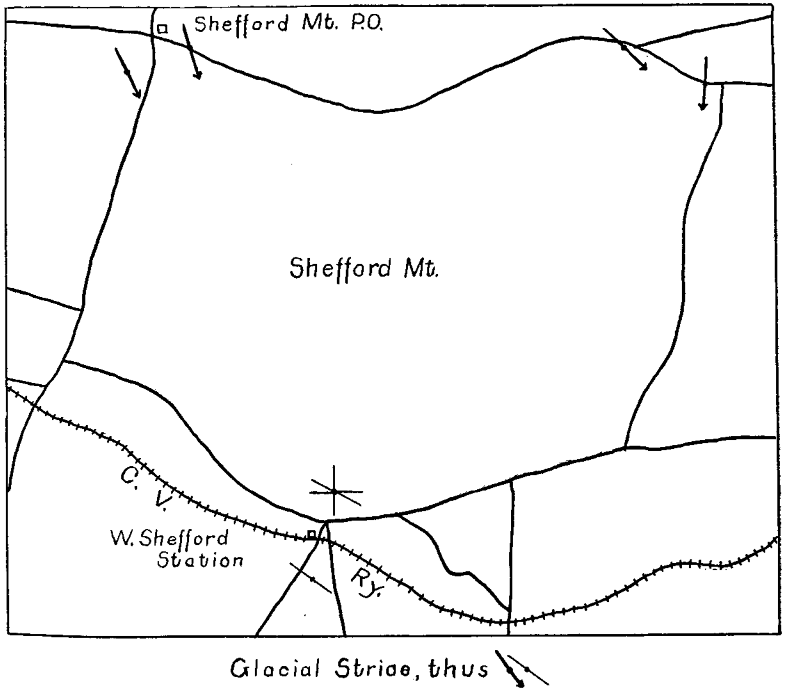


Fig. 2.—Map of glacial striae on the upturned sedimentary rocks around the base of Shefford Mt., Quebec.

The sketch map (Fig. 2) shows the glacial striae observed around the base of Shefford Mountain. The directions of the striae on the convex north slopes of this isolated mountain are consistent with the idea that the main current of ice at the time the striae were made was west of the mountain and was directed southward along the axis of the Champlain valley. In this case the striae on the south (lee) side of the mountain might be crossed in directions, as they are found to be.

In each valley of northwestern Vermont the glacial striae lie nearly parallel with the axis of the valley, whether the valley is longitudinal or transverse. There is, however, a well-marked tendency toward a N. W.–S. E. direction, if the striae are all considered together. This is good evidence that there was a strong movement of ice southward in the Champlain valley after the region just east of the Green Mountains was nearly free from ice. Taylor (1903, p. 363) finds evidence in the Berkshire Hills that the Green Mountains were an effective barrier to the eastward extension of the ice-front during its retreat from western Massachusetts. For a long time after the main portion of the ice-front began to be confined to the western side of the Green Mountains there were still remnant tongues pushing eastward through the gorges of the Winooski and Lamoille rivers. In the Winooski gorge, near Bolton, roches moutonnées with the plucked sides on the east give conclusive evidence of such movement.[1] The effects of these tongues of ice in the gorges upon the drainage of the valleys east of the Green Mountains will be considered in succeeding paragraphs.

SHORE-LINES IN THE CHAMPLAIN LOWLAND.—It is convenient to begin with the southernmost shore-line features to be considered, and proceed northward. The location of the places mentioned may be found on the map, Plate xxi.

Bristol to the Winooski Delta.—The Middlebury sheet shows the village of Bristol to be situated on a terrace 600 feet in elevation. A mile west of the village, north of the railroad crossing, there is another terrace at the altitude of 490 feet. From the description which C. H. Hitchcock ('61, vol. 1, p. 131) gives of the surface of these terraces and from their topographic relations, I am led to classify them as deltas and shore-cliffs, and to correlate them with the two highest stages of Lake Vermont, namely—the Upper Coveville and the Coveville.

Beginning at Bristol and extending north to Hollow Brook, on the east side of the Hogback Mountains, there is a longitudinal valley,

[1]I have not noticed any evidences of local glaciation in northern Vermont. Chalmers ('98, p. 28) and Upham ('95, p. 18) are of the opinion that considerable bodies of ice remained in and east of the Green Mts. after the Champlain valley was free of ice.

part of which drains northward by Lewis Creek, and part southward by Beaver Brook. The south-draining part of the valley was evenly graded by a filling of water-laid deposits, and was afterward trenched by stream erosion.[1] It is from this valley that the Bristol delta extends. The large amount of water-laid materials in the valley, and the size of the Bristol delta make it evident that no small amount of drainage from the ice coursed through the valley while the delta was building into Lake Vermont. The altitude of the valley deposits makes it seem probable that the process of valley-filling began during the latter part of the existence of Lake Albany.

When the ice-front had receded so far as to free this valley of ice, it at the same time left free the valley of Hollow Brook, which comes into this valley from the east. There is a conspicuous terraced delta at the mouth of the Hollow Brook valley. The top of the highest terrace (665 ft.) is about 20 feet too high for it to be considered contemporaneous with the highest level of the Bristol delta, allowance being made for tilting according to the evidence given by certain shore-line features on the New York side of Lake Champlain. Yet these deltas in Vermont are so much better defined, and so much further north of the Coveville outlets of Lake Vermont, that they probably more accurately define the slope of the Upper Coveville stage than do the shore-line features in New York. Furthermore, if the southward tilting of the shore-lines is due to unloading of the land at the north as the ice-sheet melted, then the first formed shore-line should slope more than those formed later, provided, of course, that uplift took place at intervals during the unloading, as well as at intervals since.

The Hollow Brook delta is much too large to have been built during the life of Lake Vermont by any stream or ice discharge from the basin which the brook now drains. An explanation of the existence of the delta is found three miles up the valley at a divide between Hollow Brook and a stream which flows into the Winooski River. In the water-laid deposits which cover the surface at this divide there is a stream-made trench about 50 feet deep. The floor of the trench is only a few feet higher than the upper level of the delta. This trench is evidently the abandoned outlet of a lake which occupied the lower part of the Winooski basin. As a further confirmation of this

[1]It is from the U. S. topographic maps, and the descriptions in Hitchcock's report ('61, vol. I, p. 131, 141) that I get the facts concerning the deposits from Bristol to Hollow Brook.

idea, I found banded clays dipping west in the valley east of the divide.

Wave lines marked by rounded cobbles and patches of gravel occur at heights of 240 and 265 feet above the sea, near the northern cross-road on the low limestone ridge leading southwestward from Vergennes.[1] In the clayey walls of a drainage ditch one fourth of a mile west of the railroad station at Vergennes at an altitude of 180 feet, I collected ten valves of *Macoma groenlandica.* These marine shells had been transported, I believe, a little way off shore from where they had been living in the shallow water at the base of a limestone hillock. The shells occur about 50 feet below the upper marine limit.

About four miles east of Vergennes, Little Otter Creek flows out of a basin about two square miles in area through a gap in the western rim of the basin. The rim at the gap is composed of till. The lower parts of the surface of the gap, between the 260 and 280-foot contours, are strewn with boulders which are evidently a concentration due to the removal of the fine material in which they were enclosed. I recognize here characteristics of wave and current work, rather than those of stream work. I explain this occurrence of boulders, on the hypothesis that when Lake Vermont was lowering, the basin behind the gap held an arm of the lake. When the surface of the lake had fallen so as to nearly expose the low part of the rim of the basin strong scouring began. The last part of the scouring may have been done by tidal currents, for the position of this boulder-bed falls in line with the upper marine limit.

The two small streams next west of this locality flow from narrow swampy areas which meet the spurs of the hills abruptly, as if the swamps were formed by the silting up of bay heads. The swamps are at approximately the level of the bouldery slopes above described (270 feet).

Four miles north of Vergennes, the cross-road leading west from Shellhouse Mountain crosses a boulder-strewn surface at about the 270-foot contour. This wave line follows the contour of the hill northward for 2 miles to a projecting point where the signs of wave action are strongly developed. North of the point there is a delta-filled embayment.

At a lower level (200 feet), and a mile southwest of the line just described, a gravelly ridge, having the proper topographic aspects

[1]This ridge was mistaken by Baldwin ('94, p. 172) for an esker.

of a barrier beach, extends along the road from Vergennes to Ferrisburg. For 20 feet above this level many of the rock knobs are bare, as if wave washed.

From a well-defined cobble beach 1 mile east of Shelburne Falls, a line of wave action may be followed for 4 miles near the 310-foot contour. Northward, this shore-line becomes less distinct and appears to split up into two lines marked by terraces at elevations of 290 feet and 320 feet, east of Shelburne Bay.

The Winooski Delta. Opposite the north shore of Shelburne Bay, about 2 miles from the last locality mentioned, the 290-foot level is again represented by a terrace. Terraces with broad flats appear below this one, at altitudes of 220 feet and 120 feet. These terraces are all sandy. Comparison of them with terraces on the immediate shores of Lake Champlain, leaves no doubt that they form parts of abandoned shore-lines, the materials of which they are composed being the delta deposits of the Winooski River.

Two miles further east, near the head of Potash Brook, a shore-line appears which may be traced along near the 400-foot contour, for 3 miles. Where this shore-line reaches the hills, pockets of pebbles may be found in many of the small embayments.

From 1 to 3 miles south and southeast of Essex Junction, near the former head of the Winooski delta, terraces at elevations of 400 to 410 feet, and at 500 to 520 feet, overlook the deep trench which the river now occupies. Traces of the 400-foot level may be found on the low hill 2 miles west of the head of Potash Brook.

The Lamoille Delta. Sand flats, rising from 380 feet in altitude near Milton to 395 feet a few miles further up the Lamoille River at East Georgia, and covered in places with drifting dunes and irregular patches of gravel, give general but rather indefinite evidences of a water-level which falls into the plane of the upper marine limit. Making allowance for tilting of this plane between Milton and East Georgia, the water-level which determined the surface of the sand flats must have persisted for a long time. A number of isolated hills rise abruptly out of the delta. Their modifying influence on the distribution of currents probably had much to do with the apparent indefiniteness of the shore-line on the delta. No higher shore-lines were found in this vicinity. It may therefore be inferred that the ice still occupied this part of the Champlain valley when the high terraces of the Winooski delta and of the deltas further south were building into Lake Vermont.

St. Albans Bay. Along the shores of St. Albans Bay narrow terraces and wave lines occur at vertical intervals of from 5 to 20 feet up to the height of 150 feet above the level of the Bay.

The Missisquoi Delta. The lowest terrace of the Missisquoi delta that I studied is the one at an elevation of 305 feet. Two or three feet below the surface of this terrace, in the gravelly top-set beds, I found three specimens of a gastropod of an undetermined species, and more than one hundred valves of *Macoma groenlandica.* From this occurrence of marine shells and from occurrences elsewhere in the Champlain district (Woodworth, 1905, p. 208–216) it is clear that marine waters must have stood as high, at least, as this terrace.

The highest point at which sands occur which I can definitely refer to the delta deposits of the Missisquoi River, is at an elevation of 380 feet. This occurrence is near the railroad station at Highgate Center, about 60 feet below the supposed upper marine limit at this place.

There seems to be no way that the sea could have entered the Champlain valley except around the eastern borders of the ice as the ice-front receded from its contact with the hills northeast of this part of Vermont. Why well-defined shore-lines do not occur here at what has been considered the position of the highest marine level is an open question.

Upham (1895) and Woodworth (1905, p. 202) have supposed the indefiniteness of the upper marine shore-line on the northwest side of Lake Champlain to be due to a readvance of the ice into the northern part of the Champlain valley at the close of the upper marine stage, or later. Such an advance would account for the absence of any clearly recognizable beaches above 400 feet in elevation in Vermont, north of St. Albans. The trace of the upper marine shore-line projected northward, crosses the Missisquoi valley near Enosburg Falls, nearly twenty miles east of Lake Champlain and fifteen miles east of the part of the Missisquoi delta where marine shells have been found. Three miles south of Enosburg Falls at the altitude of the upper marine limit (430 feet) the road between East Berkshire and West Enosburg follows a low esker for a mile. The slopes of the esker and of the low ridges east and west of it appear to have been unaffected by wave action. The north end of the esker is buried under the sandy deposits of the terraces of the Missisquoi River. It seems, therefore, that this part of the Missisquoi valley was still occupied by ice at the end of the upper marine stage.

Summary and Conclusions.—The east side of Lake Champlain is bordered by abandoned shore-lines referable to several stages of a glacial marginal lake, and to several marine stages. The relations of the various shore-line features which have been found may be seen in figure 3, on which the relative distances from north to south, and the relative altitudes of the shore-line features are plotted. The delta terraces and beaches along the line L M are so near together and so strongly developed that they appear to belong together, and to mark the stage which was longest, and in which wave action accomplished most. Reference to Woodworth's (1905, p. 226) chart, which was constructed in a similar way, shows that a line parallel to L M and not more than twenty feet below it represents the upper marine stage for the New York side of Lake Champlain. That these lines are in the same tilted water-plane there can be little doubt. Lines drawn parallel to L M through the points above it are related in the same way to lines on Woodworth's chart. I have, therefore, adopted the names which Woodworth used for these water-levels.

The fact that the shore-lines on the Vermont side of Lake Champlain are twenty feet higher than those on the New York side warrants the two conclusions that uplift has been greater on the Vermont side, and that the line of maximum tilting slopes S. S. W.

SHORE-LINES IN THE VALLEYS OF THE HIGHLAND OF NORTHWESTERN VERMONT.

General Statements.—Sections in glacial deposits of several of the valleys in the highlands of northwestern Vermont show beds of well-laminated clay scores of feet in thickness. These are undoubtedly quiet water deposits. In several localities such clays are found to be overlain by till, or are much disturbed at the surface, as if they had been overridden by ice. In other localities gravels having a kame topography overlie clays. It seems then that either local or more widespread advances of the ice took place which must have effaced the shore-lines of the bodies of water in which the clays were laid down. For this reason only those structure sections which could be consistently related to existing topographic features of shore-lines have been given weight in the following discussion.

From what has previously been said about the tongues of ice pushing eastward through the water-gaps of the Green Mountains, and from the topographic relations of the valleys east of the mountains, and also from the facts—which are discussed later—concerning the water-laid deposits in the valleys, the following synopsis of the development of drainage in the valleys during the last stages of their occupancy by ice may give the reader a means of correlating some of the apparently isolated facts which are mentioned later.

If we consider a valley already partly filled with water-laid deposits to be over-ridden by ice which moves up the valley, then, when the ice begins to retreat, a lake may form between the ice and the head of the valley, discharging either down the valley under or around the ice, or across a divide into another valley.

In such a lake outwash from the ice might be spread in broad sand-plains at approximately lake-level around the tongue of the glacier during a period of halting. Such sand-plains might be so effective a barrier as to prevent the water of the lake from falling immediately to a level appropriate to the next halt of the ice. If a complete barrier was not formed the lake would fall to its next level during the withdrawal of the ice. Then a new outwash-plain and other shore-features would develop, giving the former lake basin two sets, if the water-level did not fall so much as to drain the valley. After successive drops in the level of the lake the head of the valley would be above water and thus subject to river erosion. One of the later stands of the lake might last long enough to allow the inflowing river to grade its course, build a delta and develop flood-plains. While the river was at a grade, a large part of the valley filling might be removed by lateral swinging of the river. Thus only flanking terraces would be left to mark the former lake-levels. Let the lake-level to which the river is graded drop again. The river would be permitted to partly consume its former flood-plains and develop new ones.

Now if, to the history so far outlined, there are added two complications, namely—that instead of one valley there are three parallel valleys, which during certain periods of the ice retreat were intercommunicating, and that during this glacial history and subsequently there has been tilting of the land on which the records of the lake-levels have been made, then the chief conditions which have obtained in the western Vermont valleys will be recorded.

THE WINOOSKI BASIN.—*Side Valleys.* One of the first lakes to form in front of the ice in the Winooski Basin was north of the swampy divide, at an altitude of 990 feet, between the Dog River, which is one of the southern tributaries of the Winooski River, and

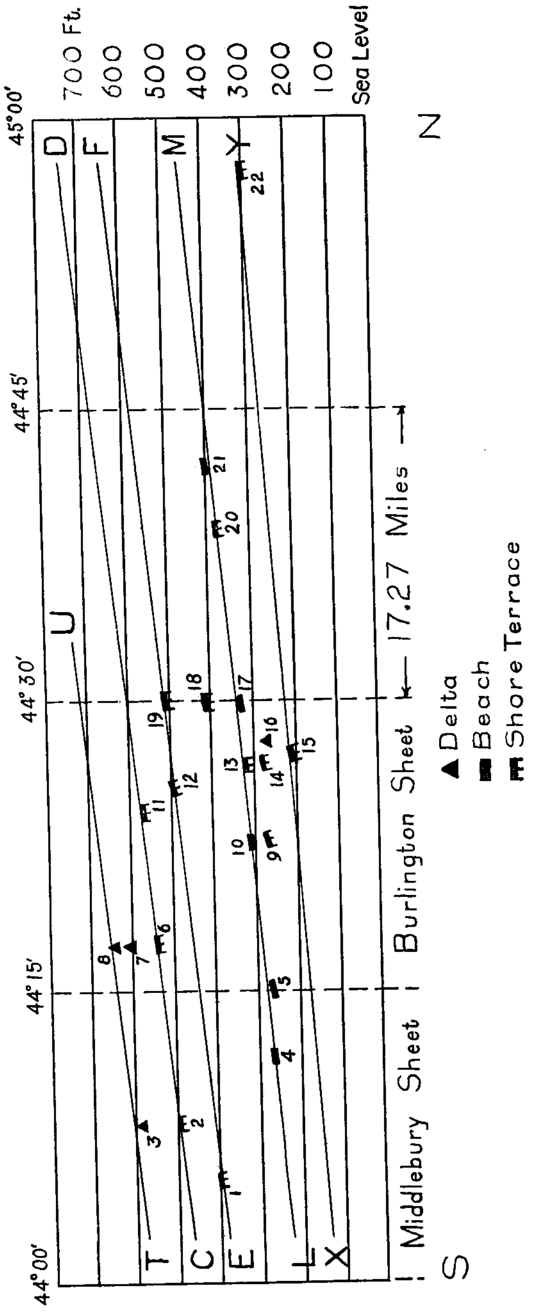


Figure 3

Merwin — Shore-lines.

FIGURE 3.

North-south profile of shore lines along the eastern side of Lake Champlain.

C–D—Coveville stage of Lake Vermont.
E–F—Wood Creek stage of Lake Vermont.
L–M—Upper marine stage.
T–U—Upper Coveville stage of Lake Vermont.
X–Y—The two wide terraces through which the line X–Y is drawn are the most strongly developed ones next below the upper marine level. For this reason they have been considered contemporaneous. The gentler tilt of the line thus drawn is consistent with the idea that it represents a marine stage after uplift had begun.

1. Terrace at New Haven Mills (see Middlebury sheet), 390 ft.
2. Terrace at Bristol, 490 ft.
3. Delta at Bristol, 600 ft.
4. Beach near Little Otter Creek, 270 ft.
5. Beach near North Ferrisburg, 270 ft.
6. A narrow terrace on the south side of the Hollow Brook delta, 540 ft.
7. The broadest level of the Hollow Brook delta, 625 ft.
8. The highest level of the Hollow Brook delta, 665 ft.
9. Terrace near Shelburne, 280 ft.
10. Beaches east of Shelburne Falls, 310 ft.
11. Terraces about Richmond, 570 ft.
12. Terraces west of Richmond, 500 ft.
13. Terraces east of Shelburne Bay, 310 ft.
14. Terraces east of Shelburne Bay, 290 ft.
15. Terrace near the mouth of Potash Brook, 290 ft.
16. Delta near the mouth of Potash Brook, 220 ft.
17. Strong beach lines south of Essex Junction and east of Muddy Brook, 340 ft.
18, 19. Terraces east of Essex Junction, 410 ft., 510 ft.
20. Terraced sand flats west of Milton, 380 ft.
21. Terraced sand flats south of East Georgia, 395 ft.
22. Terrace on the Missisquoi delta, near Highgate Center, containing marine shells, 305 ft.

the Third Branch of the White River, which is tributary to the Connecticut River.

Extending north from the divide at Roxbury, there is a sand-plain which rises northward to a height of twenty feet above the divide, where it joins an esker about one third of a mile long. On the east side of the head of the sand-plain an ice-block hole has a delicately marked shore-line about its rim. Such a line may be ascribed to lake ice action along the shore, rather than to waves.

A massive sand terrace which appears two miles north of Roxbury on the east side of the railroad at an elevation of 975 feet was probably built in a marginal lake.

Three deltas, further down the Dog River valley, in the vicinity of Northfield, at an elevation of 940 feet, were all possibly built into one lake. One delta is at the mouth of a tributary entering the Dog River from Northfield Centre, another is east of the Northfield railroad station at the mouth of a small brook, and the other is one and one half miles south of Northfield on the east side of the river.

Two and one half miles south of Northfield terraces, which are gravelly, occur on the sides of the valley at heights of 845, 830, 820 feet above the sea. They were probably cut by streams marginal to stagnant ice. Terraces due to three successive periods of grading of the present stream are found below the gravel terraces. The upper one, at an elevation of 775 feet, is much broader than the rest, and dies out further down the valley. Inasmuch as I found no barriers down the valley to account for these periods of grading, I have supposed that they were caused by successive lowerings of a lake which formed the local base-levels. Evidence of a lake at this 775-foot level is found northward, three miles further down the valley, where a delta-like deposit occurs at the mouth of Jones Brook. The upper terrace shown in Plate xxii, fig. 1, is also at this elevation. It is across the river from and about half a mile north of Jones Brook and the village of Northfield. The lower terraces shown in the view are of the same origin as those described at the beginning of this paragraph. Similar terraces occur still further north.

In the north-south valley next east of the Dog River valley a lake formed north of the 890-foot divide near Williamstown. This divide is in a swamp which drains both northward into the Winooski River and southward through the Second Branch of the White River into the Connecticut River. Immediately north of the divide the valley floor is occupied by a lakelet about one half a mile long, probably an ice-block basin, and by a small esker with a bordering belt of kames. A little further north the stream draining the pond falls over a 20-foot ledge into a swamp.

South of the divide there are two other small lakelets in rock basins. Beyond them, southward, the valley floor has been swept nearly clear of glacial materials by the temporary discharge of the glacial lake north of the divide. Still further south the flat valley floor gives place to a narrow postglacial gorge with cascades. Below the cascades the gorge widens considerably and is floored with alluvial deposits over which the small stream meanders. The excavation of this part of the gorge was evidently done by a larger stream than the present one, for the present stream is aggrading here. Part of the excavation is probably preglacial, most of the remainder was done by a glacial stream while an ice-tongue still projected south of the divide. Only a small part seems to have been done by the water flowing from the glacial lake behind the divide, for erosion has not been great near the divide and the small lakes in the path of such drainage have not been filled.

The ice-front stood for some time about three miles north of the divide, discharging debris into a lake which occupied the site of Williamstown. A section about twenty feet in depth near the railroad station shows by the crossbedding that the discharge from the ice was southward, but the top-set beds of this delta were not found at a height greater than twenty feet below the divide which held the lake in. This fact testifies to the early establishment of drainage down the valleys around the ice. To have allowed this the ice must have been in large part stagnant.

The divide at Williamstown is the lowest one between the Lake Champlain drainage and that of the Connecticut River. It is about 400 feet higher than the highest stage of Lake Vermont. Therefore Lake Vermont never had an outlet into the Connecticut River.

Between Williamstown and the main valley of the Winooski River the railroad traverses an area of typical kame topography of which the many unfilled basins at an altitude of about 760 feet are evidence that lacustrine conditions did not prevail above this elevation after the valley was free of ice.

At the junction of this side valley with the main valley there are, however, broad flats underlain by horizontal fine sands at a height of 745 feet above the sea. A mile up the side valley a narrow embayment is fringed with distinct marks of a shore-line at an altitude of 750 feet.

The only one of the valleys tributary to the Winooski on the north which I visited is the Waterbury valley. This valley has been referred to as the most typical of the longitudinal valleys. It lies east of Mt. Mansfield. At the mouth of this valley, as well as in the main valley of the Winooski, terraces composed almost wholly of clay rise nearly 100 feet above the river and over 500 feet above the sea. Clays are found also up the Waterbury valley at an altitude of over 700 feet.

The divide on the valley floor between the Waterbury valley and the valley of Joes Brook—which slopes northward—is only 740[1] feet above the sea. The surface at the divide is wholly made up of water-laid gravel and sand. The aspect of the eastern part of the divide is shown in Plate xxii, fig. 2. Here it is seen as two well-marked terraces about 15 feet high and 400 feet wide, trending squarely across the valley. The terraces are about three fourths of a mile long, and although they appear horizontal, they slope westward along their trend about 60 feet per mile. At their eastern ends they grade into kame terraces which border the valley for miles, at their western ends they die out in a broad, sandy plain. The eastern part of the upper terrace is crossed obliquely by inconspicuous terraces which radiate from its southeastern margin. A small stream enters the valley near this point. The terraces face a nearly level valley floor below which the small stream and the Waterbury River are entrenched a few feet.

Northward from the edge of the highest terrace the gravels become hummocky, a few kame kettles appear, and near the 700-foot level clay becomes conspicuous, even on the knolls. The clay is clearly a lacustrine deposit.

It is apparent then that stagnant ice was present during the deposition of the gravels and that the valley north of the divide was occupied by a lake after the disappearance of the ice.

Although my studies were not detailed enough to give data for a thoroughly satisfactory explanation of the origin of the terraces, I feel sure that they represent approximately the levels at which lake

[1]Four barometric determinations from Waterbury (427 feet) gave a mean of 690 feet for the altitude of Stowe (hotel steps).

waters stood, submerging the lowest part of the divide.[1] The altitudes of beaches near Montpelier (735 feet) and near Morrisville in the Lamoille valley a few miles north of this divide (760 feet), are further evidence that water stood high enough to over-top the divide. I have called this water body Lake Mansfield because of its topographic relation to Mt. Mansfield.

—. — *Main Valley.* The upper Winooski valley between Plainfield and Montpelier is deeply filled with water-laid deposits which rise to an altitude of 750 feet.[2]

On Seminary Hill in Montpelier a section exposes the following sequence of deposits. Upon a thick base of clay there rests 6 feet of horizontally bedded fine sand. The sand is followed by 4 feet of gravel in thin broad lenses. The contact of the gravel and sand is so nearly a plane that I believe the gravel has been dragged from a beach by wave-currents, over off-shore sands, during the lowering of the water-surface under which the sand was laid down. The slope of the gravelly surface is a few feet per hundred upward from this locality to the hills, the line of meeting being about 675[3] feet above the sea. A level at a corresponding altitude, and gravel-covered, occurs east of Washington Street in the city of Barre. Pebbly ridges crossing this flat near Main Street I have considered to be beach lines.[4]

The Winooski valley westward from the Green Mountains has an upper terrace level at 565 feet above the sea. This is best represented northwest of the village of Richmond. It is found also on the south side of the valley, extending east of Richmond about three miles to the mouth of the Huntington River, which comes into the Winooski River from the south. This set of terraces corresponds to the Coveville stage, Lake Vermont.

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[1]Either the terraces were cut and leveled by wave action—which seems improbable because they slope—or they were made by a stream which was confined by ice walls on both sides. Evidence of an ice wall on the north side is at hand, but such evidence on the south side I did not notice. The brook entering the valley at the east end of the terraces, acting with water from the melting ice, is a possible terrace-making agent.

[2]Clay and cross-bedded gravel dipping east were noted in a cut west of the viaduct in Plainfield, at an elevation of 750 feet.

[3]The altitudes in the vicinity of Montpelier are referred to Montpelier Junction (522 feet). The railway stations in Montpelier are not more than 5 feet lower.

[4]Contorted clays under this terrace, I have taken as an evidence of re-advance of the ice.

West of Richmond there is a terrace level along the 500-foot contour aggregating several square miles in area. This has already been referred to as one of the upper levels of the Winooski delta in Lake Vermont. All the terraces in the vicinity of Richmond below an altitude of 500 feet must be stream terraces, unless there was a rise in the level of Lake Vermont after the river had trenched its delta and developed flood-plains accordant with the lake-level.

Two and one-half miles south of Richmond, near Owl's Head hill, banded clays occur in roadside cuts at an altitude of 645 feet. East of the hill a deeply dissected sand-plain attains the observed elevation of 650 feet. Outwash from the ice is the only probable source of the materials in these deposits. This sand-plain must have been built into a lake tributary to Lake Vermont during a part of the Upper Coveville stage of Lake Vermont. The presence of the ice as far south as this locality at this time supports Woodworth's belief that at the time of the Upper Coveville stage the ice impinged against the mountain side as far south as Port Kent, New York.

THE LAMOILLE BASIN.—*The Main Valley.* I traversed the Lamoille valley from Milton near its mouth eastward to Greensboro-bend near its source.

The most elevated sections which gave evidence of origin in standing water are well up the river, in the village of Hardwick. Near the railroad station at this place, at an altitude of 895 feet, cross-bedded sands enclose numerous clods of stony till. East of the village, at an elevation of 1055 feet, a large body of gravel, apparently of proglacial-delta type, forms a flat surface half a mile wide. The level of the water in which this deposit was made was high enough to have extended northward into as much of the Lake Memphremagog valley as may have been free from ice at that time. Certain high-level terraces in that valley Hitchcock[1] has correlated with stages of a glacial lake which he has called Glacial Lake Memphremagog.

If the amount of tilting has been correctly measured, the lake at Hardwick at the 1055-foot level could not have drained into the Connecticut River, for the lowest point between the basins of the Connecticut River and the St. Lawrence River was then higher than this lake. (The point is near Williamstown at 890 feet.) The drainage was probably southwestward, along the ice-front.

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[1]C. H. Hitchcock, High level gravels in New England. Bull. Geol. Soc. Amer., 1894, vol. 6, p. 460.

A few miles further down the river, one mile west of Wolcott, an exposed section of a delta shows fore-set beds dipping south, and top-set beds of thin lenses of gravel. At the level of the top of this section, 800 feet in elevation, there is a delta-like deposit at the cemetery northeast of the village and broad terraces at the mouth of Wild Brook, two miles west of the village. The water-body standing at this level could not have drained northward into Lake Memphremagog. Because it was confined to the Lamoille valley it seems appropriate to call this body of water Lake Lamoille.

Still further down the river, near Morrisville, the Lamoille valley widens broadly, where it is met on the south by the Joe's Brook valley. Sandy plains with small dunes and gravelly ridges cover an area of several square miles. On the hill slopes between Joe's Brook and the Lamoille River irregular, terrace-like forms cross the Elmore road at an elevation of 950 feet and lower. At 790 feet, 760 feet and 725 feet above the sea, parallel gravelly ridges from 1 to 3 feet high, each below a terrace cliff and separated from it by a slight depression, border the valley southeast of Morrisville. The terrace cliffs face the valley. The ridge below the cliff at the altitude of 760 feet has an exposed cross-section showing the gravel of which it is composed to be distinctly cross-bedded, the dip of the beds being toward the adjacent terrace cliff. The topography and structure of this gravel ridge and the topography of the adjacent country all support the idea that the terrace cliffs here are wave-cut, and that the low ridges below them are barrier beaches. Moreover, a water-level at about the altitude of the highest of these terraces is necessary to account for the clays, and the northerly drainage of the valley of Joe's Brook.

The larger part of the floor of the valley about Morrisville is very evenly filled to an altitude of about 660 feet.[1] The river is deeply trenched below the surface of this filling. A hundred acres or more of the surface of the northern portion of this plain consists of such loose gravel that there is not sufficient water retained at the surface to support any noticeable vegetation except mats of the lichen, *Cladonia rangiferina,* and a few trailing blackberry bushes. This deposit is near the head of what must have been a glacial sand-plain, for no other source of such material seems possible. At Hyde Park, three miles down the river from Morrisville, the plains above the river are at this altitude (660 feet). In fact, the upper terrace level for the next fifteen miles down stream, as observed in several places, is about 650 feet above the sea. The one farthest west is on the south side of the river at Jeffersonville. An eastern spur of this terrace is separated from the adjacent hill slopes by a depression which is strewn with angular boulders. The ice must therefore have been present in the depression while the terrace was forming.

[1]Large masses of highly contorted clays may be seen in the eastern part of the village at about this elevation.

This terrace level, reaching from Morrisville to Jeffersonville, could not have been made before the Coveville stage of Lake Vermont, for this stage of the lake attained an altitude of 650 feet at Jeffersonville. That much of the material of the terraces was deposited directly from the ice in deep water is shown by irregular cross-bedding in cuts near Jeffersonville and near the railroad station at Johnson, and also by regularly south-dipping gravel beds midway between Hyde Park and Johnson. The presence of ice during the deposition makes it probable that several lakes at approximately the same level occupied the valley, discharging from one to another westward, through broad channels, rather than that a single body of water extended the entire length of the part of the valley in which the terrace was observed.

A terrace at the 620-foot level, having much the same origin as the one at the 650-foot level, extends interruptedly from Hyde Park to Jeffersonville. At this level, the spur of the terrace at Jeffersonville, mentioned in the preceding paragraph, is covered to a depth of nearly 2 feet, with a concentration of pebbles, a large part of which are from 1 to 4 inches in diameter. The valley here, at the time of this terracing, seems to have been free enough of ice to permit considerable wave-cutting on this spur.

For the eight miles next west from Jeffersonville the Lamoille valley is floored with water-laid materials which are dune-covered in many places. Terraces at observed elevations of 535 to 550 feet and 485 to 500 feet were seen on both sides of the valley. Numerous sections indicate that, at least locally, lacustrine and fluviatile conditions have alternated more than once since the filling of the valley began.

—. — *The Side Valleys.* Fifteen miles east of Lake Champlain Brown's River enters the Lamoille River from the south. In the eastern junction angle between the streams, sand terraces reach an altitude of about 540 feet. Terraces are absent from the north side of the Lamoille River in this vicinity on account of the presence of ice there during the building of the terraces on the south side. Brown's River had no part in this terrace-building, for it drains an unfilled basin of which the terrace deposits are the northern rim. The Brown's River valley, during the Wood Creek stage of Lake Vermont, was submerged by an arm of the lake at least 100 feet. Into the north end of the valley at this time sediments collected from the ice and from the Lamoille River; into the south end the Winooski delta encroached; into the middle, only a little sediment from small side streams, and clay from the ice, found their way. Corresponding to this level of Lake Vermont, beaches were formed northeast of the northward bend of the river at an elevation of 510 feet and three miles north on the east side of the valley, wave-washed slopes at about 515 feet.

When Lake Vermont began falling from its Wood Creek stage the Lamoille River still drained through the lake in the Brown's River valley. Its old channel across the Winooski delta is at an altitude of 490 feet. Very soon, however, the ice in the lower Lamoille valley gave way, allowing the Lamoille River to occupy its preglacial channel. The lake in the Brown's River valley then began draining into the Lamoille River.

From near Jeffersonville a longitudinal valley extends northward, joining the Lamoille valley and the Missisquoi valley. The swampy divide on the floor of the longitudinal valley attains an altitude of about 450 feet. South of the divide kames and outwash gravels rise to an elevation of 550 feet. Southwest of the divide laminated clays occur 30 feet above the divide. The clays are overlain by gravels which form an ice-block basin south of the cross-road leading to North Cambridge. Here the clays dip south. These relations are explainable on the hypothesis that the clays were laid down in a lake standing at an elevation of 580 feet or more, and that an advance of the ice over them left a stranded ice-block.

THE MISSISQUOI BASIN.—*The Side Valleys.* The northern part of the longitudinal valley just described also contains glacial outwash gravel. At Sheldon the gravels attain a height of 450 feet above the sea, and at the divide between Sheldon Springs and Green's Corners, a height of 460 feet. The latter deposit is irregularly cross-bedded and contains scattered boulders reaching four feet in diameter.

Half a mile east of Green's Corners, stratified clay with a thin

capping of gravel was found at an altitude of about 440 feet. This clay is high enough to have been laid down in Lake Vermont shortly before the marine invasion, but if it was so deposited the deposition took place prior to the last appearance of the ice in the vicinity, for west of Green's Corners a till plain forms the valley floor a hundred feet below the altitude of the clay.

About eight miles west of the Green Mountains and midway between the Lamoille River and the Missisquoi River, in another longitudinal valley, a sand-plain nearly a square mile in area has an altitude of about 600 feet.[1] The village of Bakersfield is situated upon it. A mile northwest of Bakersfield and at the same level there is a small trenched preglacial delta with an ice-contact on the north side. Only a few rods west of the little delta, a well-defined esker, extending northward, ends abruptly in a transverse valley. No recognizable relation exists between the sand-plain and the esker, though the esker is more than a mile long, and in places more than 100 feet high. Half a mile southeast of Bakersfield the sand-plain gives place to kames amongst which two lakelets fringed with sphagnum bogs still remain.

Two and a half miles west of Bakersfield on the road to East Fairfield, banded clay which contains scattered boulders as large as a foot in diameter was found in a cut at an altitude of about 500 feet. The boulders were probably dropped by floating ice. It is very probable that the waters of Third Lake Lamoille extended far enough north to have determined the level of the Bakersfield sand-plain and other lacustrine deposits in the vicinity.

—. — *The Main Valley.* The uppermost terrace along the Missisquoi River north of Bakersfield and Sheldon is so gently sloping down the valley that, whether it is entirely due to stream aggradation or to a combination of processes such as have already been discussed, it can be but a few feet above the level of a body of water into which the river emptied at the time the terrace was forming. An ice barrier at the mouth of the valley, or an arm of the sea at a stage immediately succeeding the upper marine stage may have determined the altitude (430 feet) of this terrace.

SUMMARY AND CONCLUSIONS.—The main valleys of northwestern Vermont drain westward. Owing to their opening into the low

[1]This figure is based upon several barometric determinations from Swanton as a base. The figures for the altitudes of Sheldon and E. Fairfield are interchanged in Gannett's Dictionary.

Champlain valley, which largely controlled the direction of retreat of the Wisconsin ice from the region, the heads of the valleys were first freed of ice. Marginal lakes then collected between the ice-front and the divides. The first lakes to form were at the head branches of the Winooski River. Each of them for a brief time spilled over into the Connecticut River drainage. The last marginal lake in the Winooski valley to abandon the Connecticut River drainage was a small one north of the 890-foot divide near Williamstown. This happened before the lakes in the branch valleys had become confluent, and from this time drainage took place beneath or around the ice into the Champlain valley. As the ice withdrew further and the lakes coalesced the First Lake Winooski stages were entered upon. (See map.)

By this time, in the Lamoille valley, a similar lake was growing. At an early stage it is probable that it drained northward through the Lake Memphremagog basin. The stages preceding this probable stage have been called First Lake Lamoille, and those immediately succeeding, Second Lake Lamoille.

As soon as the ice no longer obstructed the valleys east of the Green Mountains, First Lake Winooski and Second Lake Lamoille met in the longitudinal valley east of Mt. Mansfield, thus introducing Lake Mansfield stage.

Lake Mansfield came to an end when its level dropped enough to cause a division between the waters that occupied the Lamoille valley and those which occupied the Winooski valley. This division brought into existence the Second Lake Winooski and the Third Lake Lamoille stages.

With further retreat of the ice-tongue which occupied the western part of the Winooski valley, a strong discharge of glacial waters took place through an arm of Lake Winooski, which stood high enough to drain across the divide east of Hollow Brook.

Subglacial communication was soon after established between Lake Winooski and Lake Vermont, and then Lake Winooski dropped to the level of and coalesced with Lake Vermont.

At this time the ice still obstructed the Lamoille valley. It was not until Lake Vermont had fallen to its Wood Creek stage that Lake Lamoille became directly confluent with it, first through the Brown's River valley and later through the present valley.

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PLATE XXI.

A. Sketch map of northwestern Vermont. Key to abbreviations.

B.—Bakersfield.
Ba.—Barre.
Br.—Bristol.
Bu.—Burlington.
E.—Essex Junction.
E. F.—Enosburg Falls.
E. G.—East Georgia.
F.—Ferrisburg.
G. C.—Greens Corners.
H.—Highgate Centre.
Ha.—Hardwick.
H. Bk.—Hollow Brook.
J.—Jeffersonville.
Jo.—Johnson.
Lan. R.—Lamoille River.
L. Mem.—Lake Memphremagog.
L. Ot. Cr.—Little Otter Creek.
M.—Milton.
Mis. R.—Missisquoi River.
Mo.—Morrisville.
Mp.—Montpelier.
Mt. M.—Mt. Mansfield.
N.—Northfield.
P.—Plainfield.
R.—Roxbury.
Ri.—Richmond.
S.—Stowe.
S. F.—Shelburne Falls.
St. A.—St. Albans.
V.—Vergennes.
W.—Williamstown.
Wa.—Waterbury.
W. Bk.—Wild Brook.
W. E.—West Enosburg.
Win. R.—Winooski River.
Wo.—Wolcott.

B.–F.—Diagrammatic maps of certain lake stages in northwestern Vermont.

B. a.—A marginal lake south of Northfield (945 ft.).
b.—Lake Williamstown (890 ft), discharging into the Connecticut River.

C. a.—Second Lake Lamoille just after falling below the level of the divide at Eligo Pond (900 ft.).
b.—First Lake Winooski at a stage represented by an altitude of about 745 feet at Plainfield.

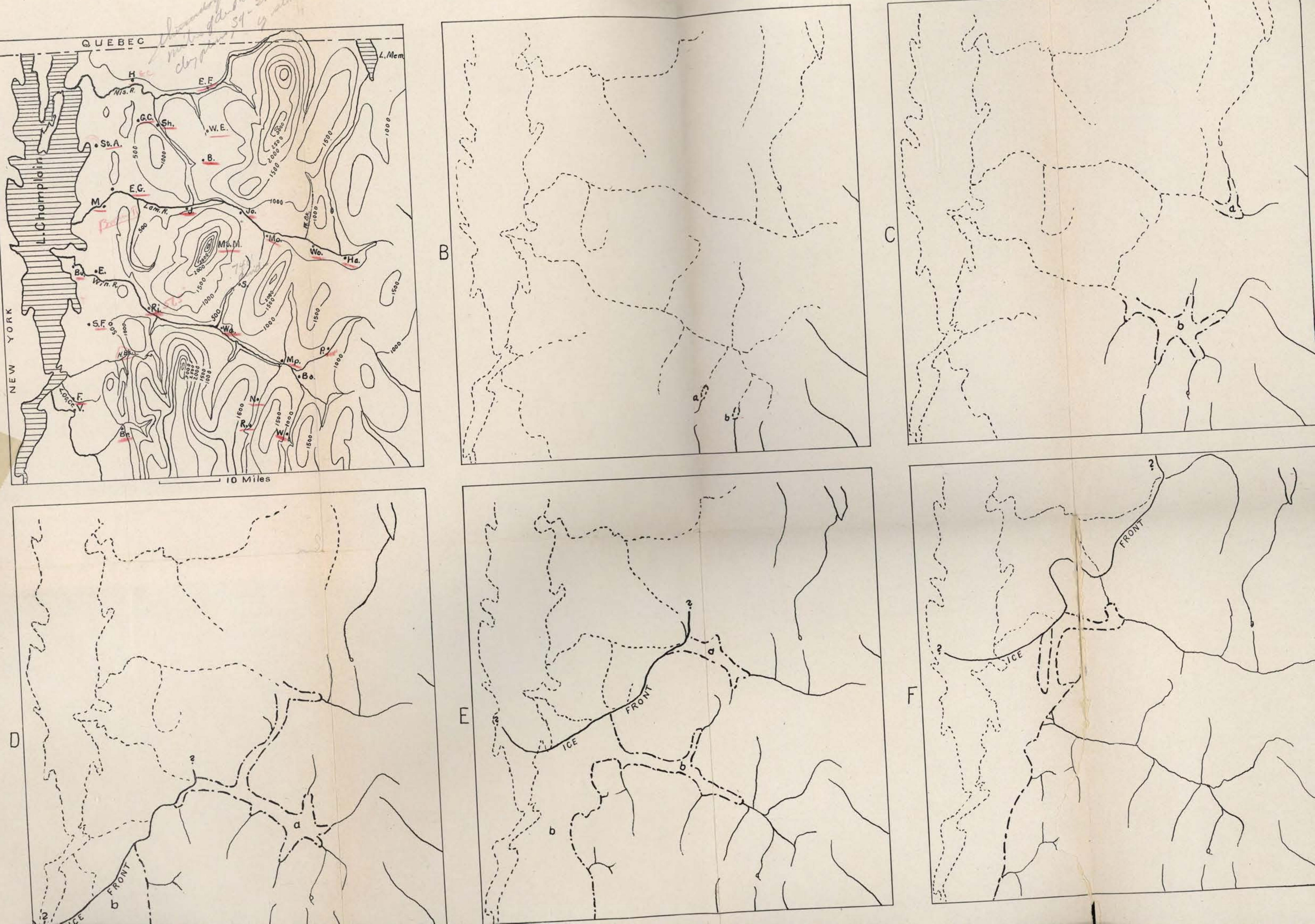
D. a.—Lake Mansfield. The terraces and beaches in the vicinity of Montpelier at 650 to 675 feet in altitude and those near Morrisville at 760 to 790 correspond to the level of this lake. Ice in the vicinity of Richmond held the water of Lake Mansfield somewhat higher than the level of Lake Vermont or the last stage of Lake Albany (b.).

E. a.—Third Lake Lamoille (650 ft.) during a part of the Coveville stage of Lake Vermont (b).

F. —Wood Creek stage of Lake Vermont. The lines between the question marks in the last three diagrams represent hypothetical ice borders.

[From Bulletin No. 7, Vol. VIII, Geological Series, Museum Comparative Zoology, Cambridge, Mass.]

A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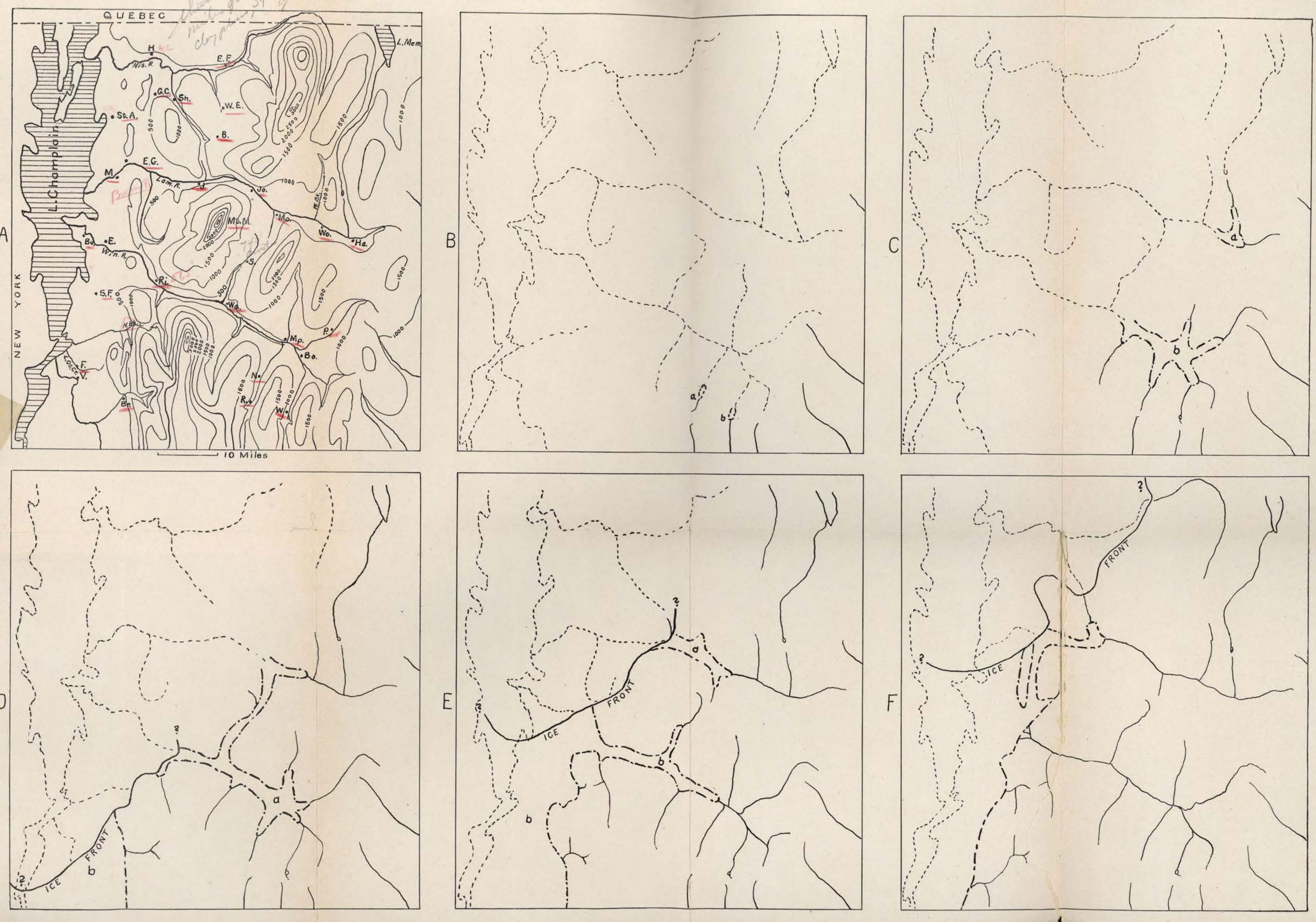
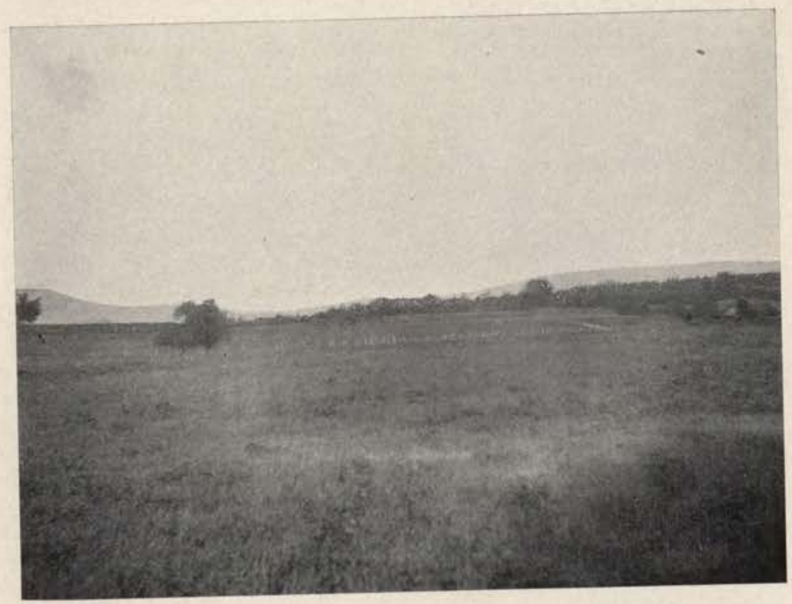


Sketch Map of Northwestern Vermont.

PLATE XXII.

Terraces on the Dog River, one mile north of Northfield, Vt.



Terraces at the divide east of Mt. Mansfield, between Stowe and Morrisville, Vt.

REPORT

OF THE

STATE GEOLOGIST

ON THE

Mineral Industries and Geology of Certain Areas

OF

VERMONT.

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SIXTH OF THIS SERIES.

GEORGE H. PERKINS, Ph. D.

State Geologist and Professor of Geology, University of Vermont.

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CONTENTS.

LIST OF PLATES.

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Geology of the Hanover, N. H., Quadrangle.

C. H. Hitchcock.

The United States Geological Survey has just issued one of their quadrangles upon the scale of one mile to the inch, $\frac{1}{62500}$, for the area of 223.5 square miles upon which the village of Hanover, N. H., is situated. About two thirds of the area is in the state of Vermont, including parts of Norwich, Sharon, Pomfret, Hartland, Windsor and West Windsor and the whole of Hartford. As every one knows, the east border of Vermont is the west shore of Connecticut River at low water mark. It will take sixteen quadrangles the size of this one to complete the area of a square degree of latitude and longitude. The Hanover quadrangle is embraced between latitudes 43° 30′ and 43° 45′, and the longitude 72° 15′ and 72° 30′. The Strafford quadrangle lying just north of the Hanover area was published in 1896, and the Sunapee quadrangle just touches the Hanover quadrangle at its southeast corner. All three quadrangles have the same scale and their combined area is isolated from all others.

Topographically the Hanover quadrangle is marked by the valley of the Connecticut River running about N. 15° E. S. 15° W., and by the large tributaries, White and Ottaquechee rivers, upon the Vermont side. In Hartland there is a smaller tributary known as Lull's Brook. Upon the east side are three tributaries of about the size of Lull's Brook, viz.: Mascoma River in Lebanon, Blood's and Blow-me-down brooks in Plainfield. The exact altitudes of the larger rivers are as follows, as corrected from former statements, in Bulletin No. 274 of the U. S. G. S.:

CONNECTICUT RIVER.

Windsor (lowest point in quadrangle),	294
Hartland,	303
North Hartland,	315
White River Junction,	325
Norwich bridge,	365

Pompanoosuc River, mouth,	367
North line of Norwich,	370

OTTAQUECHEE RIVER.

Mouth, at North Hartland,	315
Below woolen mill,	320
Above woolen mill,	340
At bridge, road to Hartford,	360
Head of rapids,	380
Town line, Hartland and Hartford,	420
One mile north,	440
Lower end of gorge,	460
Near Woodstock R. R. bridge,	480
Dewey's mill, near,	500
Below falls at Quechee village,	520
Mouth of Whitman's Brook,	580
Between Whitman's Brook and Taftsville,	600
Woodstock,	700

WHITE RIVER.

Mouth of White River, at junction,	325
Dam at Hartford,	340
Centerville near R. R. bridge,	360
A little above West Hartford,	380
Above mouth of Mitchell Brook, Sharon,	400
Near north line of Hanover quadrangle,	420
One and one half miles below Sharon village, Strafford quadrangle,	440
Two miles above Sharon, Strafford quadrangle,	460

The Mascoma River falls from 545 feet at Lebanon to 323 at its mouth.

RAILROAD STATIONS.

Windsor,	321
Hartland,	416
North Hartland,	380
White River Junction,	461
Norwich and Hanover,	365
Lebanon,	552
West Hartford,	424
Sharon,	500

HIGHER PEAKS IN THE HANOVER QUADRANGLE.

Pomfret, highest point, Thistle Hill,	2,000
Seaver Hill,	1,960
Vail Ridge,	1,560
East of Vail Ridge, Sharon line,	1,520
Bunker Hill,	1,520
Norwich, Griggs' Mountain,	1,800
Gile Mountain (Strafford sheet),	1,917
Stone Hill (Strafford sheet),	1,680
Meeting-House Hill, north (Strafford sheet),	1,201
Hill west of New Boston (Strafford sheet),	1,482
Hill one mile east of Gile Mountain (Strafford sheet),	1,700
Hartford, Neal's Hill,	1,300
Hurricane Hill,	1,220
Height of land, Birch school,	1,010
Hills northeast of B. S.,	1,040
Hills north of Quechee village,	1,160
East of Jericho,	1,280
Hartland, southwest from Taftsville,	1,400
Kent Hill,	1,680
Hill south,	1,780
Road south,	1,510
Hills south of road,	1,536, 1,480, 1,560
West Windsor, northwest corner,	1,280
Hill south,	1,700
Other hills,	1,600
Windsor, northwest corner,	1,280
Cornish, N. H., Fernald Hill,	1,540
Plainfield, Fifield Hill,	1,272
French Ledge,	1,340
Colby Hill,	1,340
Morgan Hill,	1,423
Governor's Hill,	1,100
Lebanon, Farnum Hill,	1,306
Crafts Hill,	1,080
Quarry Hill,	1,080
Mt. Finish,	980
Colburn Hill,	1,000

Hanover,	Velvet Rocks,	1,200
	Reservoir,	697
	Observatory,	603

ALTITUDES IN THE STRAFFORD QUADRANGLE.

Chelsea,	Holt Hill,	1,775
	Merrill Hill,	1,764
	Near south corner,	2,180
Vershire,	height of land, road from Chelsea (near west line),	1,950
	Hill south,	2,260
	Colton, highest summit in quadrangle,	2,412
	Patterson Mountain,	2,321
	Goodhue's Ledge,	1,820
	Eagle Ledge,	1,859
	Hill one mile east,	2,027
	Gilman Hill,	2,065
	Northwest of copper mine,	1,880
Strafford,	Whitcomb Hill,	1,859
	Richardson Hill,	1,715
	Davidson Hill,	1,740
	Macmaster Hill,	1,960
	North of Macmaster Hill,	2,000
	One and one half miles south of north corner,	2,020
	Near north corner,	2,200
	South of Kibling Hill,	1,986
Tunbridge,	Brocklebank Hill,	2,120
	Curtis Hill,	1,561
	Williams Hill,	1,940

Theoretically it is supposed that the original surfaces of the two quadrangles constituted a great plain, with a drainage southward along the course of the Connecticut River, and that this plain has been excavated by the streams flowing through it down to their present levels. The original surface has sometimes been termed a *peneplain,* and much speculation as to its erosion in the several later periods has been indulged in. If the present elevated points should be imagined to be connected by a sheet or plane the present position of a peneplain might be reconstructed. The easiest method of perceiving this plain in the field is to look at the summits extending

northerly as one stands at the base of the granite cone of Mount Ascutney. Such a sheet would stand at about 1,100 or 1,200 feet at Ascutney and rise gradually to Thistle Hill in Pomfret, 2,000 feet, sloping very materially to the Connecticut. From Thistle Hill its elevation would be much the same through Norwich, rising in Strafford and culminating in Colton Hill, Vershire, at the altitude of 2,412 feet. It may be conceived that the variable heights of the peaks in this section have been determined by their hardness or ability to resist erosion. Thus Thistle Hill may have been originally of the same altitude with Colton Hill, but the former is now lower because of its greater susceptibility to decay. And there are considerations leading to an understanding of an approximate limit to the early upper surface, based upon the geological history of such elevations as Mount Ascutney, Brocklebank Hill and the great granite area east of Montpelier. These eminences have a granite core known geologically as a batholith. When soft this material filled cavities below the surface and was prevented from escaping by walls of the rocks surrounding the igneous core. Were the heated mass like a modern volcano the lava would flow from the surface. In case such a flow ever existed over the batholiths all traces of the streams would have disappeared long ago, and the fact still remains that the igneous core was kept in place by the enveloping rock.

Upon considering the altitude of this ancient plain it must have been higher than the top of the batholith; or in the present instance a few hundred feet higher than the top of Mount Ascutney, say 3,500 feet above the present sea level. The core resisted decay far more than the adjacent rocks, so that now the granite remains at 3,186 feet, while the highest points of the adjacent peneplain range from 1,200 to 2,000 feet. In other words the rock has been excavated over the Hanover quadrangle from 3,500 feet down to the present surface, or nearly 3,000 feet at the Connecticut at Windsor and 1,200 feet at Thistle Hill. And it is easy to show that the erosion over the whole of the surrounding country, or New England, has been as great—probably greater—than over our quadrangle. Though of enormous proportions erosion has been much greater over the Cordilleras region on the west side of the continent.

The rocks of the quadrangle have been extensively folded and faulted and are usually tilted more than forty-five degrees, being both stratified and unstratified. A few years ago the order of the formations seemed to have been well made out and they were correlated with both the Archean and the Paleozoic. With greater knowledge the Archean has been excluded because the foliated schists so referred are found to contain fragments of the latest stratified rocks occurring in their neighborhood. These inclusions bear witness both to the igneous character of the rocks and to its late origin. There are no fossils in any of the later groups, so suggestions as to their age cannot be decisive. Under these circumstances, it is not possible to do more than to classify the groups according to mineral characters, with hints as to their probable age derived from the supposed continuations of the strata from Vermont into the adjacent regions of Canada and Massachusetts where they may have been satisfactorily made out.

For convenience the rocks may be arranged as follows:

1. The hydro-mica, chloritic, and sericite schist groups.
2. Argillites.
3. Coös mica schists.
4. Calciferous mica schist [Conway].
5. Coös quartzite.
6. Conglomerate group.
7. Amphibolites.
8. Granite.
9. Basic dykes.

CHLORITIC GROUP.

Petrographically this will indicate hydro-mica, chloritic and sericite schists, igneous protogenes, diorites, diabases, sandstones of various degrees of alteration, argillitic schists, hornstones, quartzites and limestones, constituting truthfully a complex. In the Vermont Reports it had the general name of Talcose schist; in the New Hampshire Reports it was known first as the altered Quebec group of Canada, afterwards as Huronian, and locally the Lisbon, Swiftwater and Lyman schists, all in the Connecticut Valley, in distinction from a similar broad area extending through Vermont from Canada to Massachusetts. The two ranges have been supposed to be of the same age connected as a synclinal fold beneath the various mica schists. Only the eastern range appears upon the Hanover quadrangle.

As to age, provided the two ranges are indentical, it may be partly Cambrian and partly Ordovician; at least the geologists of Canada and Massachusetts give these references to the same rocks within their limits, the latter not using the term of Cambrian for them. As

nothing new in respect to its age can be learned from our studies upon this quadrangle, it is not needful to insist upon its precise place in the geological column. Without fossils it is always difficult to recognize the age of any metamorphic group, based as it must be upon petrographic resemblances and stratigraphical relations.

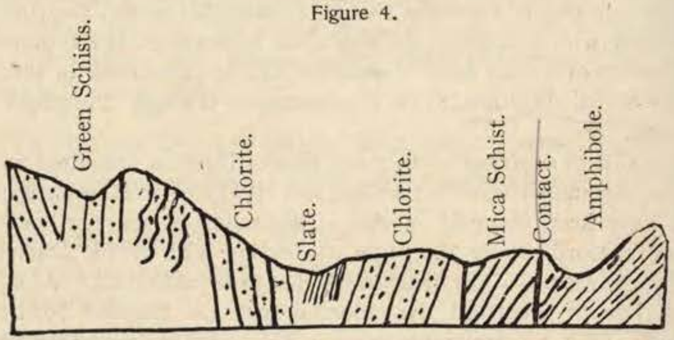
This chloritic band enters Norwich at Union village with a width of a mile and one fourth, and then very shortly reaches our quadrangle just west of the Poor Farm. It extends through Norwich and Hartford with a slightly broader area adjacent to the Connecticut and passes over into New Hampshire at the great bend in the river about North Hartland. It is continuous through Plainfield into Cornish.

The planes supposed to be those of stratification are tilted at high angles, commonly near to vertical, and it will be well to mention all that have been observed in detail, beginning at the north end, in East Thetford, along the route of Section VII of the Dartmouth College Museum. The structure seems to be anticlinal. Along the south line of Thetford the chloritic rocks at the east border are massive, with no apparent strata. There are as many as twenty ledges of this sort in S. H. District No. 3. To the west is a chlorite schist, dipping 78° S. 45° E., followed by novaculite, argillitic schists, slaty layers much bent and dioritic schists on the hill overlooking Union village. On both sides of the Pompanoosuc River at Union village the strata are vertical with the strike N. 80° E. The western border dips very high to the N. W. In Norwich close by the hill overlooking Union village are chloritic and dioritic schists, dipping S. E. In the southeast corner of the Strafford sheet near the Norwich Poor Farm the sericite schists are very nearly in contact with the mica schists to the east, along a deep, narrow valley. The former are bent into small contortions, averaging 80° easterly dip, while the latter dip as low as 50° to the west. There is probably a fault here, rather than an unconformity. The strikes of the two rocks are different.

A section from Bradley Hill to Blood Mountain, fig. 4, near the northeast corner of the quadrangle shows the relations of the several rocks to each other. On the west side of Bradley Hill are the argillites. On the hill itself are the chloritic schists, slightly argillaceous, with the dip N. 50° E. At the cross roads the schists are more sandy, vertical. Farther east they are much twisted, 70° N. 30° W. An anticlinal next, the sandy schists at J. O. Johnson's dipping 85° S. E. The same at O. Seaver, followed by a band of argillite, 80°

N. 38° W., where measured, but probably a synclinal, as everything on the east side dips 70° N. 40° W., especially by the old S. H. No. 5, on the Thetford road. The schists are massive and chloritic here. There must be a fault on the east border of the green schists, as they come in contact with the Coös mica schists, a band of rock terminating beneath the modified drift west from Tilden pond.

Figure 4.



Section from Bradley Hill to Blood Mountain.

East of the slate band the chloritic rock is rather ill defined all the way from the great bend of the Connecticut near Loveland's down to the Ledyard bridge. Near the first island there are the quartz schists altered by contact with hornblendite and dolomitic appearing material minutely contorted with easterly dips. This is all to the east of a band of argillite. On the west side the dips are all northwesterly to the edge of the formation near schoolhouse No. 4 composed of the following varieties: Argillitic schist, bands of chlorite schist, green chlorite, the same becoming white when weathered, brownish layers more siliceous, granite bunches, large white quartz veins, massive and slaty chlorite, massive argillite schist, steatite and chlorite schists. The width directly across the formation, section 1, is a mile and a quarter, with the average dip of 70° at the steam sawmill and at the turn of the road to the village of Norwich there is a wide belt of schists altered to epidotic, serpentinous and brecciated masses, east of the same argillite noted above. To the west the schists are chloritic, sandy and argillitic back of the village, especially to the east and north, and the strata are nearly vertical. The following positions were noted here: 70° N. 57 W., 90° with strike N. 5° W., 78° N. 40 E., 90°, and 50° N. 60 W. The very western border

PLATE XXIII.

Quarry in Green Schists, Hartford.

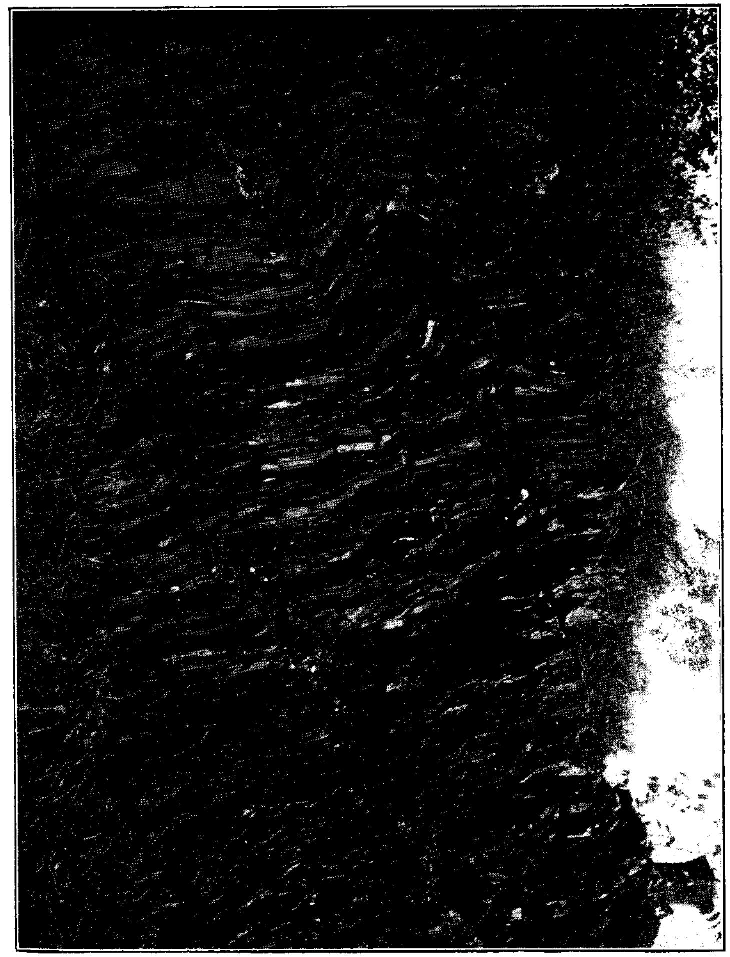
The best dip is 65° S. 60° E. The schists are cut by dikes of diorite, are much broken by faulting, but the blocks are cemented together firmly. This state of things may represent the conditions prevailing all over the region; the rocks have been fractured everywhere, but the blocks have been cemented together so closely that they will not separate any more readily along the planes of fracture than elsewhere. The individual blocks may vary in size from a brick to a township. The country has, therefore, been subjected to repeated and violent earthquakes in its early history. The ledges under the iron bridge represent the west border of the chloritic schists; the argillites come in just below the dam. South of the river at the Hartford station of the Central Vermont Railroad are fine illustrations of bent strata, exhibited in Plate XXIV. Similar ledges appear along the Woodstock Railroad a few feet higher up. These rocks may represent the transition from the schist to the argillite.

The relations of this formation along White River, as just described, are shown graphically in Section 3, Plate XXIVa.

Nearly two miles southward from the Junction are two conical summits, each 700 feet high. The east one is composed mainly of hornstone and a compact diabase which suggests an igneous mass such as might be called the base of an ancient volcano. The western one is probably identical in character with this. And there are two similar cones in the very southeast corner of Hartford, of which the more eastern is a protogene carrying inclusions of green schist, so indestructible as to make a great bend in the river. There must have been another scene of igneous activity at the falls of the Quechee near the woolen mill at North Hartland, where green schists running nearly east and west have been cut at right angles both by the more compact diabase and dikes allied to camptonite.

A section across the chloritic group near Kilburn brook about two miles from the Junction gives us hornstones close to the Connecticut River, dipping 80° N. 80° W., 70° N. 60 W., at the brook itself chiefly hornblendite, 75° N. 80° E., less than a mile back from the river, and vertical schists on the Hartford-North Hartland road, at the east base of Neals Hill. This gives a synclinal altitude to these schists along the line of Section 4, Plate XXIVa. This formation crosses the Connecticut at North Hartland. In the river are remnants of green schist resembling the piers of a bridge, dipping westerly, and northeast at the "Hen and Chickens." The rock may be traced southerly into Willard's ledge and Prospect Hill in Plainfield. It is a compact diabase at the ferry, a green diabasic schist on the

PLATE XXIV.



Contorted Strata, R. R. Cut, Hartford station, C. V. R. R.

north slope of Willard's ledge, dipping N. W., dioritic at its western base, soft sericite on Beaver Brook.

The situation is made interesting by the discovery of limestone, quartzite and conglomerate, evidently continuous from exposures two miles southwest of the Junction to Prospect Hill and unnamed high hills upon the boundary between Plainfield and Cornish.

Near the hornstone hill at a sharp curve in the river are ledges of hornblende, mica schist and two feet of a saccharoidal limestone, most of them minutely contorted with a general position of 85° E. 10° S., and more or less interstratified. They suggest the Coös schists and the hornblende is probably of sedimentary origin, and there are ledges of it on the Lebanon side. Close at hand and back from the river in Hartford there are three hummocks of conglomerate, having distorted pebbles with mica-schist strata adjacent rising from the modified drift. Half a mile farther south in a railroad cut, there predominates chloritic schist with breccia and a grayish limestone dipping 70° N. 70° W. These rocks are thought to be a continuation of those just described on the river's bank. I have failed to find this assemblage, save a quartzose breccia east of Willard's ledge, till Prospect Hill in Plainfield is reached, 1,154 feet high. A section across it reveals a dip of 57° N. 70° W., the rocks at the west end being slaty and much contorted. The limestone is of considerable breadth containing epsomites or stylolites, tantalizing one by their resemblance to fossil shells. There is a hornblende rock on the east side.

On the south side there is a synclinal in hard green schist, in which the limestone is again developed. The schists are strangely contorted in this neighborhood. By analysis the limestone proves to be a dolomite and its soft nature has developed a small valley.

There was a discussion in the New Hampshire Report whether these rocks could belong to a later group called Helderberg.* On the hilltop 1,128 feet on the Plainfield-Cornish line, a similar limestone crops out, formerly quarried and manufactured into quicklime. The dip is 80° N. W. Above it on the west is a beautiful quartz conglomerate, which can be followed for several hundred feet, in one place showing a fault and throw to the east. Green schists intervene between the limestone and the quartzite. The limestone also occurs in Cornish about a mile from the line.

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*Geol. N. H., Vol. II, p. 396.

In attempting to correlate this series of rocks from Hartford to Cornish one is reminded of the Silurian limestones and overlying conglomerates in Lisbon and Littleton, where characteristic fossils are found.* At the present writing such suggestion seems plausible, even if it carries some of the green schists with them. At this more southern locality the strata are greatly contorted and broken up.

ARGILLITE.

A broad range of slate or argillite flanks the green schists upon the west side. The material is mostly a distinct slate of fine grain and nearly vertical cleavage planes. Of late there has been a careful search for ledges where the planes of both stratification and cleavage may be found where the latter have not obliterated the former. Most satisfactory examples were first found in Thetford in material more sandy than common. The strata are contorted, dipping northerly at a low angle, 10°–15°, while the part thoroughly schistose beneath dipped 50° N. 60° E.

Better illustrations are to be found near W. F. Davis' in District No. 1. These showed dips of 12° northeasterly and the cleavage is nearly vertical. At Mr. Davis' the dips are 52° N. 30° W., and the cleavage 85° N 30° E. In a precipice close by, the strata dip 40° in the same direction and are obvious in the presence of many layers of white quartz. At the covered bridge over the Pompanoosuc, a mile further north, these strata dip 20° northerly and the cleavage planes 50° S. E. The slates at Thetford Hill seem to be pinched out at Union village and to return to their former breadth farther west towards Meeting-House Hill. The dips are high, westerly through Districts 8 and 6, and the rock is banded. In District No. 20 the slates are close to the green schists, dipping the same way, 75° N. 60° W.

On the road to Sharon by a sawmill the distinct coloration of the strata is seen with a very high dip. Farther west a dike of Camptonite has been intruded between them. By E. B. Brown's, the first house just beyond a fork in the road, the position of the overlying mica schist is the same. Several ledges farther north by W. Brigham's and J. Sprout's exhibit vertical strata. Upon the stream descending from the Bragg schoolhouse the slates dip 80° N. 70° W. At the eastern edge there seems to be a mass of them that have

*New Studies in the Ammonoosuc Field: Bulletin, G. S. A., Vol. XV.

slidden over the green schists for a considerable distance. Between the Bragg schoolhouse and Dothan there is the same high dip, N. 70° W.

In the valley of White River many observations have been made which show vertical strata, in Hartford village near the church and upon the hills north, the last displaying small zigzags with the general strike of N. 20°–30° E. At the junction of the road from the north with the one running west from the village, the position is 85° S. 70° E., and the ledges are plenty. At the mouth of the stream from Savage Hill the dip is 75° S. 60° E., so that there is a synclinal axis in the slate along White River. Passing to the south of Neal's Hill, the formation widens at Schoolhouse 14, and upon Hurricane Hill the position is 85° N. 70° W. The positon is about the same on the south slope of Neal's Hill.

A section across the band in District No. 12 would indicate a synclinal in the whole of the eastern half exhibiting contorted strata. Illustrations of the divergent cleavage and strata planes are to be found in North Hartland at the railroad crossing one mile south from the station and west of the church on the hill. The strata dip 36°–50° N. 37° W., and the cleavage planes are vertical.

In passing into Plainfield the slates become more sandy and their bulk greater. In the New Hampshire Report they were ranked as a part of the Calciferous Mica Schist over Home Hill. Several outcrops were noted on the road close to the river through Plainfield with easterly dips. At the Quechee (Sumner) lower falls the cleavage dips 75° N. 60° E. Turning up Home Hill the dip is 60° E. 70° S., and the ledges numerous; on the summit of Home Hill there is a mass with a zigzag direction, having the general dip E. 20° S. and a small amount of limestone. The same rocks extend down the east side of the hill; and upon Clay Brook in the edge of the village of Plainfield the slate dips 50° S. 60° E. The position is about the same southwest from the village, and in the west corner of Cornish, and an anticlinal at the mouth of Blow-me-down Brook. Near the town line at the east edge of the formation, near the top of the ridge, nearly 900 feet, the slates dip only 10° northerly and the impression is made that these slaty rocks in the corner of Plainfield and Cornish consist of broken segments separated by a fault, in which the continuity of the axis cannot be easily traced.

The southeast corner of the quadrangle just touches an equally important range of argillite, which has been traced from Guilford and Vernon through Brattleboro to Springfield, and then across the Connecticut to Claremont and past Cornish Flat to East Lebanon and beyond along the west side of Moose Mountain.

It is like the range just described in being adjacent to the Conway mica schists for much of its course and must be of the same age, though not so regarded in the New Hampshire Report.

The narrow range of slate in the green schist west of the Connecticut in Norwich has been already referred to.

MICA SCHIST GROUP.

The greater part of the Hanover quadrangle is occupied by the Coös and Conway mica schist groups. In the report for 1861, my father wrote the chapter on the mica schist and brought out a name which has been used extensively, and it is proper to make a brief historical sketch of all the terms which have been used for these rocks in this neighborhood.

In the older days geologists preferred to use petrographical terms for formations instead of geographical, as gneiss, mica schist, talcose schist, etc. Hence the 1861 Report gave the general name of mica schist for all these rocks in eastern Vermont. A few of the areas included were described under this general appellation, but the greater portion were known as the Calciferous mica schist, following C. B. Adams, who had denominated them as Calcareo-mica slate. The following quotations will clearly define the views of the Principal of the Survey: "The normal description of this rock (mica schist) makes it consist of alternate layers of mica and quartz . . . the most important variety so far as Vermont is concerned is where the rock takes into its composition carbonate of lime. It does not simply contain interstratified beds of the lime, but the two ingredients interpenetrate each other, sometimes one predominating and sometimes the other. This we call Calciferous mica schist, and it so predominates in the state that we have sometimes doubted whether all the various schists that exist there were not originally of this description, and subsequently deprived of its lime, in some cases by metamorphic action." Page 475. "8 Calciferous mica schist. This is the Calcareo-mica slate of Professor Adams and has already been partially described. We prefer the name calciferous to calcareo-mica schist, as being rather more appropriate and euphonical. For in general the basis of the rock is mica schist which bears the limestone." Page 476.

Upon the map the two mica schists are distinguished from each other, and the areas collectively correspond with those now termed Conway and Coös. Concerning the terminology I remarked in the Geology of New Hampshire, Vol. II, p. 395, 1877, that the petrographical expression "ought to be replaced by a geographical designation."

Professor B. K. Emerson in Monograph XXIX, U. S. G. S., 1898, p. 177, remarks that the name calciferous mica schist "is objectionable because it is used in England for a sub-division of the Carboniferous and in America for a sub-division of the Silurian, and in the uncertainty concerning the age of the beds here described mistakes have arisen, and it has been supposed that the name carried with it an implication that the rocks were Lower Silurian. Moreover the names usually employed would indicate that the calcite was an accessory constituent of the rock, and not that beds of limestone were intercalated at wide distances in the veins."

It had not seemed to me that any serious inconvenience would be occasioned by the use of the adjective calciferous in connection with a Carboniferous sandstone in Scotland and an Ordovician sandrock in eastern America, and I should not urge that as a reason for dropping the name.

As to the question whether lime enters into the composition of the schist in addition to its intercalated beds of limestone, there seems to be difference of opinion between President Hitchcock and Professor Emerson. Future workers in this field may decide this question for themselves.

In the further prosecution of studies into the mica schist group in this state, I discovered very early that there was a large series of the non-calcareous members quite conspicuously displayed on the east side of the Connecticut, to which I proposed to give the name Coös Group in my second annual report, 1870, after the Indian name Cohos (usually spelled Coös) and to include the "argillaceous schists, whetstone schist grits of northern Coös County . . . and the similar and associated rocks" in Quebec and eastern Vermont, adding "the quartzites, staurolite rocks, micaceous schists, hornblende schists, perhaps gneiss, protogene and other rocks west of the White Mountain series and east of the Connecticut River along the whole of western New Hampshire, but excluding the Calciferous mica schist." This was the usage of all the New Hampshire reports, and upon the map of the 1878 report I colored considerable areas in Essex, Orange and Windsor counties of Vermont as belonging to this group. A greater area had not been reclaimed from the Calciferous mica schist because I did not then have the opportunity to explore further the terranes in Vermont.

There was a tendency to include some areas of the andalusite mica schist group east of the Connecticut-Merrimack divide with the Coös series. In my report for 1870 I presented several sections across this group in the towns of Hanover, Lyme, Orford and Lisbon, noting the constancy of a westerly dip and an average thickness of 9000–1000 feet.

Our present understanding of the protogene-granite gneiss and hornblende schists enumerated in the above section is that they are all of igneous origin, and as such not a part of the stratigraphical series which will reduce the thickness by 2,000 feet or more.

Dr. T. Sterry Hunt assumed that this series corresponded with his Terranovan group in Newfoundland, supposed to be roughly equivalent to the St. John's slate now established as Cambrian. In the fourth and fifth reports of the present Vermont series, Dr. C. H. Richardson has written extensively upon the Calciferous mica schist, dividing it into a calcareous and non-calcareous member, to which he at first gave the name Washington limestone and Bradford schist, changed later to Waits River limestone and Vershire schist, because the earlier names were preoccupied. From a perusal of his very complete bibliography two conclusions may be drawn as to the terminology: first, no reference is made to the Coös group, which corresponds to the Bradford or Vershire schist, and is, therefore, entitled to usage because of priority; and second, both his names were anticipated by Prof. B. K. Emerson in Massachusetts by the words Conway and Goshen. So that because of priority, the names Conway and Coös should be used, as they are in this paper, for the divisions of the mica schist group.

COÖS GROUP.

Four areas of mica schist are recognized on the Hanover quadrangle west of the Connecticut River: (1) A small division reaching from East Thetford to the Norwich poor farm; (2) From Central Thetford and farther north to Quechee village, possibly continuous with (3) from Thistle Hill, Pomfret, to the west part of Hartland; (4) Small, ill-defined areas in the southwest part.

Our work has not yet progressed far enough to authorize the establishment of a definite stratigraphical column, setting forth the precise order and thickness of the several members. Reliance is placed upon the petrographical characters for the present delineations.

The characteristic rock in these four areas is a clean mica schist, with a predominance of silica, and it is exceedingly unusual to find any limestone associated with it. I have sometimes imagined it to be the equivalent of the Coös quartzite, but the alteration seems to be a change to a foliated schist rather than the reverse. This is the rock that carries the cupiferous deposits of Vershire and Strafford. These schists are also characterized by the presence of cleavage planes, apparently identical with the stratification, at least I have not been able to find many sections like the one in southwest Thetford, where the distinction is unmistakable. The darker strata in this block lying by the roadside, carry biotite and many small garnets. These schists, being comparatively indestructible, remain as hills, like those adjacent to Tigertown Brook in southwest Norwich and southeast Sharon, West Hartford, near Quechee, the base of Seaver Hill in Pomfret, Kent Hill and the vicinity of Taftsville. Some of these hills are probably faulted blocks, the best defined examples of that nature being the continuation of the Tigertown Hill westward in Sharon upon the Strafford quadrangle.

Quimby and Baxter mountains are abrupt elevations with precipitous sides, such as correspond to fault planes. Similar mountains are Stone and Gile hills in the west part of Norwich, and the high range south from Sargent's Hill in the central part of the town.

There is reason to believe that there is quite a thickness of an argillaceous mica schist intercalated in the midst of the Conway group. Such masses are known at Chelsea and at Woodstock village, but their relations remain to be worked out. The two small areas of the Coös schist in the southwest part of Hartland may have this position.

The areas at Quechee village and Taftsville are on the opposite sides of anticlinal axis, with the Conway schists overlying them in what is conceived to be their natural order. The band connecting them at the village is concealed by the overlying modified drift, so that another interpretation of the arrangement is possible. The small outlier at the head of the spillway belongs to the Coös series.

The Coös rocks extend from near the reservoir at Hanover to and including Colby Hill in Plainfield, the materials being mica schists with and without staurolite, schists mainly argillaceous, chloritic schists, and the section adjacent to the Lebanon granite that has been greatly altered by the thermal influence of the batholith at the time of its intrusion. North of the Mascoma River the shale dips N. 30° W., from 40°–80°. The most northern section, starting from Lord and Pinneo Hills has the lower dip, the hills to the east being more micaceous and lying just outside of the quadrangle. The schists near the river are very argillaceous. Farther south, a large vein of white quartz has cut the slates and its color renders it quite conspicuous. On Balch Hill the dip is higher and the topography indicates a visible junction of the schist with the granite. The continuation of the schists southerly is concealed by a thick covering of sand and clay from Balch to the west flank of Colburn Hill, but the position is much the same in Lebanon as farther north. There is a segment of the schist on the west flank of Colburn Hill, having an easterly dip, so disposed because it is a faulted block. Crafts Hill is composed of mica schist with intruded masses and dikes of amphibolite and diabase. At the river the amphibolites have a dip of not more than 50°, then by the road it is 70°. Part way up the schist, sometimes calcareous, stands more steeply, even vertical, and suggests the continuation of the wedged segment from Colburn Hill. On the summit the dip is 75° westerly, with a few crystals of staurolite. On the east side the schists are much altered by contact with the Lebanon granite. There are a few narrow bands of quartzite on the west flank of Crafts Hill, possibly to be correlated with the Moose Mountain quartzite.

Following the ridge to the Mascoma there is an alternation of amphibolite schists and mica schist. East from West Lebanon the crystals of mica, biotite, have a large development in feathery bunches and they are found also at the north base of Farnum Hill.

Farnum Hill has a course rather northwesterly, the strata do not conform to the direction, and hence erosion must have been an important agency in fashioning its outlines. At the north end both at the base and summit the dip is 70° N. 70° W., at the south end, the highest elevation, the dip is 60° N. 50° W. Igneous dikes have produced some disturbance at the north end and the southwest side, so that many ledges do not conform to the usual arrangement. The schists assume a strike nearly north and south, with very high dips on the southwest side of Farnum Hill and near the south line of the

town, and they meet abruptly another set of strata coming from the northeast, presumably along the line of a fault.

In the earlier report the theory was suggested that the changes in the strata indicated a sharp curvature in the formation—a less satisfactory view than that now presented.

The next section of the Coös rocks is marked by the predominance of soft chloritic schists interspersed with conglomerates.

It was a puzzle to us in years past to understand why this region should afford the soft schists, which elsewhere were associated with the green sericite rocks. Now that it is recognized that the petrographic character does not correspond to age, the way is clear to advocate the existence of a later chloritic series metamorphosed from another fragmental or amphibolic mass. The probability is that this late series will be found to differ so much from the ordinary Coös mica schists that it shall not be ranked with them, but rather with the Coös quartzites which are not to be found in this quadrangle. These quartzites are composed of grains and small pebbles of quartzite. Why may not the chloritic conglomerate represent a synchronous accumulation of fragments, from which the silicious grains have been separated by a different system of currents?

It will be well to denominate this series the Coös chloritic conglomerate for the present, leaving the question of exact correlation for future studies. Thus defined, these chloritic rocks constitute a broad band entering the quadrangle at Storrs' Hill in Lebanon, running southeasterly to embrace Morgan's and Colby's hills in Plainfield, Smith's Hill, and its prolongation in Cornish.

Some of the chloritic layers merge into the mica schists between Governor's and Farnum hills in Lebanon.

The band of altered schists is simply that part of the Coös mica schists which has been affected by contact with the protogene granite of Lebanon. The thermal influences extend for nearly half a mile on the flanks, and farther beyond the southerly end of the granite. The village of Lebanon abounds in outcrops of these altered schists, which are coarse mica schists and gneisses, epidotic and hornblende.

In earlier reports they were ranked as the upper part of the protogene gneiss of the Bethlehem series. The separating lines may be well seen in the railroad cut in the west part of the village of Lebanon between Mascoma and Mechanic streets, Scytheville, and at the dam near the railroad crossing in the village. This last rock is a vertical spotted protogene with segregated veins and a syenitic aspect. There is no distinction on the map to indicate the extent of these altered schists.

CONWAY GROUP.

This calcareous division is developed in three parts of the Hanover quadrangle, first in Sharon and Pomfret, second, from Norwich to Windsor, third in the southeast portion in Cornish and Plainfield.

It is normally an argillaceous mica schist (phyllite) with beds of micaceous limestone traversed by veins of quartz, often of large size and white, occasionally by veins of granite and minutely contorted. There is not much opportunity to find cleavage planes athwart the lines of stratification because the schists and limestones are undeniably existent in layers by themselves, though occasionally traversed by cleavage planes confined to either one of the rocks.

The abundant amphibolites are supposed to be of igneous origin. The rocks are normally characteristic in the valley of White River in Sharon, extending south as far as Mitchell Brook.

On the west side this limestone is exposed in a bluff, 500 feet high, that has been cut through by Mill Brook in the northwest corner of Pomfret and under a ridge about three miles long in the three towns of Sharon, Pomfret and Hartford. It is really all massive limestone, either horizontal or dipping slightly to the east, with minute contortions and veins of quartz. There is a sudden change in dip at the boundary of School Districts No. 4 and 6, making what H. D. Rogers calls a normal anticlinal axis, with the western side much the steepest, 55° W. and 10° E.

The hills north of Mill Brook in the two towns, as well as over the whole area, are high, steep and rounded, having been worn down in the fashion peculiar to calcareous rocks.

These hills reach 1,500 feet in the edge of Sharon and upon Vail Ridge in Pomfret, upon Bunker Hill, and just touches 2,000 feet in Thistle Hill. This with Seaver Hill is a heavily wooded ridge four miles long. There were formerly roads, farms and houses along its eastern flank, now deserted and forgotten.

Some of the limestone along the southern part of the abandoned road is white and filled with excrescenses suggestive of fossils.

Bunker Hill is at the crest of an anticlinal, traced from the very north edge of the quadrangle along White River in Sharon to the end of the Conway rocks at the great bend in Quechee River and continued farther south in the underlying mica schists.

The axis is apparently shifted to the head of Happy Valley in the next area of this rock in the northeast corner of Woodstock, and has been followed by its outcrops at the south corner of school district No. 8, Hartland, along the crest of the watershed between the streams flowing into the Connecticut and the South Branch in Woodstock, to the southwest corner of Hartland.

Everywhere east of that axial line the dips are easterly through Hartland, Hartford and Norwich, to the limit of the map in Hartland. They are seen for over two miles in the middle part of District No. 10, along the valley in the middle of District No. 9, along the Alder Meadow Brook for two miles south of the fork in the roads leading to Woodstock and Taftsville, over Districts 6 and 22, in District 3 and elsewhere. This is, however, a part of the second of the areas mentioned, and the same material extends into Plainfield, where it is more phyllitic and is not clearly separable from the argillites.

It has been difficult to separate the Conway from the Coös rocks in Norwich and different statements have been made by us concerning them. The schists display more affinity with those of the Conway than of the Coös group, but there is a scarcity of limestone, becoming less abundant in going north.

A plate of sections, XXIVa, has been prepared to show the relations of these and other formations across Norwich and Hartford.

There is a synclinal in this rock upon Sections 1 and 2, broadest between Dothan and Jericho, and not recognizable much farther north, and it is also absent in the White River and Ottaqueechee valleys, sections 3 and 4. There must be a segment of the Conway rocks between White River and the Bragg schoolhouse which is a faulted block. There may be traces of this axis just in the edge of the Strafford quadrangle in a calcareous band just west of the mica schist at the Poor Farm, indicated by a fault in the section from Bradley Hill to Blood Mountain. Patches of the siliceous limestone have been obtained in several places in Norwich, as upon Griggs Mountain and the valley of Blood Brook. More or less connected with the faulting are three marked bluffs on the north side of White River, just midway between Hartford and Centerville; second, just to the west of Centerville, and third, east of West Hartford. These were probably connected with some of the vertical movements in the neighborhood.

The Conway schists are characteristically developed in Quechee Gulf, where they have been traversed by igneous dikes. The hill to the west probably belongs to the Coös division, though not so represented upon Section 4. There may be traces of the fault on Neal's Hill, where there is a lack of concordance in the dips of the adjacent rocks. East from the gulf there is an interesting inverted anticline in an abandoned quarry, the dip being S. 70° E. It is only about two feet long and is suggestive of the possibilities of structure that may yet be developed.

Hartland has not been traversed so carefully as the towns farther north. Conway seems to be the prevailing rock, with the usual easterly inclination of the strata and an occasional igneous dike.

The limestone is conspicuous in the valley of Alder Meadow Brook from a mile above the four corners to the crossing over to Babcock Brook. It is also visible in Districts 3, 5, 6 and 22. There is a large vein of white quartz in it in the south part of District No. 3. In District No. 12 limestone is abundant in the valley of Lull's Brook.

One recognizes the peculiar Conway rocks in the third area, in the southeast part of the map, in Cornish and Plainfield. On Fernald's Hill and French's ledge are domes of calcareous rocks with steep sides, just like the same material all over Orange County. The predominance of small contortions of strata and vertical position about Cornish Flat indicates great stratigraphical disturbance. A comparison of dips indicates that there is an anticlinal arrangement of the strata in this area traceable from West Claremont through Cornish to Meriden. This is like the corresponding structure noted in the west part of Hartford and Hartland.

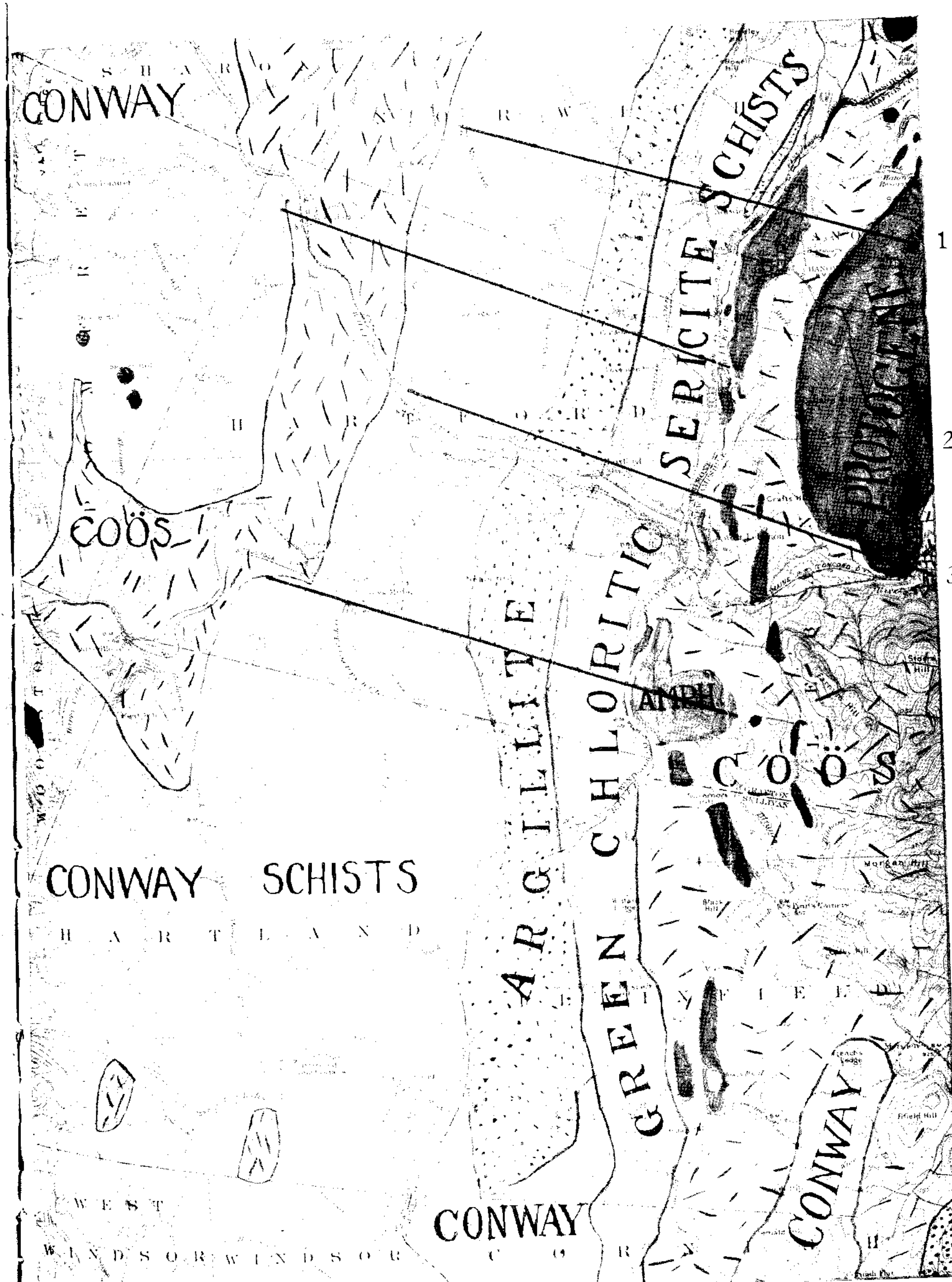
THE GEOLOGICAL MAP.

Plate XXVa.

It has not been found practicable to represent all the nine groups of rocks developed in the quadrangle for this report. Instead there has been a reduction of the nine to the dimensions of a page upon which all the formations already considered have been represented. Numbers 5 and 6 have been alluded to in the description of the Coös rocks. In a proper discussion it would be necessary to correlate them with the unique quartzites which are best displayed upon Moose and Grantham mountains, which are outside of our field of labor.

For convenience the amphiboles and granites are represented by a

PLATE XXVa.



Geological Map of the Hanover Quadrangle.
Nos. 1, 2, 3, 4 indicate location of Sections shown in Plate XXIVa.

single tint. There is only one area of granite. All the others are of the amphibolite or hornblende division. The several basic dikes would take very little space for their delineation.

AMPHIBOLITE.

No one can examine the rocks of the Connecticut Valley with care without discovering the problem of the hornblende schists. What are they? And are they altered sediments or original igneous masses? In the early days I was taught to believe in their metamorphic character; later, on discovering traces of igneous origin for some of the layers under discussion I am led to believe that both kinds may be present.

Hornblende is the black variety of amphibole, and the one most common in our section of the country. It is a silicate of lime, magnesia and iron, with variable amounts of the bases. The layers of rock holding it have every conceivable proportion of the mineral, from less than one to a hundred per cent. In the basic dikes it is both an original and an altered mineral, and it is apt to be changed into chlorite. This fact may enable us to understand the origin of the chloritic schists of Lebanon and Plainfield mentioned under the Coös group. The map gives some idea of the situation of the hornblende in the quadrangle. There is a series of outcrops extending the whole length of the map, enveloped in the mica schist.

At first it seemed to be a part of the green schist group, which it touches occasionally, but further investigation satisfies me that it is connected only with the Coös rocks. It comes in bunches. Because there are two areas apparently in a line so as to be connected beneath the surface, it seems a better inference to believe them separated by soft schist which has been disintegrated and removed. Hence instead of putting in a broad area of this rock, I have several small bunches without any connection with each other, unless it be by subterranean threads connecting each mass with the parent magma deep down in the earth.

At the northeast corner of the quadrangle is Blood Mountain, entirely composed of this rock and several times larger than what appears. Quite a quantity of copper sulphuret is found in it and was once worked for that metal in what was called the Pompanoosuc mine. The folia dip 35° N. 40° W. upon the moutnain, rising 20° at its junction with mica schist. The few small patches upon Pinneo

Hill represent a larger number just outside the limits of the map. The beginning of a larger range is at the great bend of the Connecticut River, most of the bed of which has been excavated out of it down to Plainfield. At the Dartmouth Park the outcrops are numerous and the following dips have been measured in a direct line from the eastern outcrop in the Park to the steam sawmill in Norwich, a distance of seven-eighths of a mile, 44°, 44°, 48°, 53°, 48° and 90°, N. 50° W. The schistose structure is everywhere as pronounced as is that of the schist known as altered sediments, in fact, some of the layers in the Park are believed to be sediments. This band is continuous to Wilder and all the positions have been individually measured corresponding to those already noted.

The next outcrops are upon Colburn and Crafts hills, some of them being evidently intrusive in oval masses. At low water the rock is bared at the bridges over the Connecticut at White River Junction. At the crossing of the Mascoma River the rock is pure hornblende with radiating, acicular bunches, precisely like many masses associated with the green schists. At the north end of Farnum Hill these schists have locally displaced the Coös rocks. Smaller areas crop out in the direct line south. Mount Finish is the single largest mass along its course of the rock. As represented upon Section 4, the mountain is not a uniform mass of hornblende, it is more or less intercalated with mica schists with northerly dips. At the southwest corner of Lebanon and part way up Governor's hill there is an alternation of the two kinds of schists. Where this hill is crossed by the road in Plainfield the mica prevails from the west base to the summit, the hornblende being largely developed on the east side. There is a gap in our work between this and Black Hill and the ill-defined areas farther south. At the north end of the Mount Finish area upon the west bank of the Connecticut, there is a narrow belt of white granular limestone interstratified with the hornblende and mica schist. The strata are minutely crumpled and suggestive of sedimentation.

For many years the Dartmouth Park has furnished museums with attractive specimens of hornblende schist containing small, red almandine garnets. These are perfect dodecahedrons, of a clear wine color and to the eye absolutely pure, but showing in thin microscopic sections grains of quartz. This fact would never be known except for the revelations of the microscope. The garnets do not enclose any of the hornblende, but do sometimes contain bits of magnetite.

PLATE XXVI.

Contact of Amphibolite and Mica Schist, Poor Farm, Norwich

This garnetiferous hornblende schist has been studied and described by W. S. Bayley in Bulletin 150 of the U. S. G. S. The rock is mainly hornblende and quartz in alternating folia, with garnet and biotite. The mica and hornblende have their longer axes parallel to the banding of the rock constituting the schistose structure. The hornblende is strongly pleochroic. The biotite is evidently one of the latest formed minerals. The matrix contains plagioclase feldspar, probably microcline and labradorite. Professor Bayley was unable to say whether this rock was originally a quartz-diorite, a diabase or a gabbro. Upon Crafts Hill there are dikes of diabase very like the hornblende, enough so to suggest a genetic connection.

THE CONTACT PHENOMENA.

As is well known when an igneous mass impinges against an earthy rock, the latter undergoes certain changes. A crystalline rock would not be likely to show any changes in chemical character. Now the line of contact between the more northern mass of the hornblende schist with the adjacent schist upon the west side has been followed for several miles, and evidence obtained that the former must have been in an igneous condition, and consequently the apparent planes of stratification have been superinduced since the time of eruption.

The best illustration is to be seen near Blood Mountain on the Poor Farm in Norwich. The hornblende schist is found in absolute contact with the mica schist along a nearly vertical plane running N. 20° E. The dip of the hornblende schist had been 35° N. 70° W. on Blood Mountain and over here 20° more. The mica schists have the same position and present a nearly vertical face to one looking from the east, as if the igneous rock had been more susceptible to disintegration. There are two inches thickness of garnetiferous, coarse hornblende along the plane of contact. The mica schists indicate no particular change in their character, except an increased induration. They have the aspect of faulted blocks.

Plate XXVI represents the line of contact taken from the south. A pocket handkerchief rests upon the line of contact, the mica schist rising to the left and the hornblende occupying the low ground to the right. The two rocks may be followed at close quarters for several rods to the south.

The next contact is in the bluff over the railroad at the sharp bend in the Connecticut River near Lovelands. One mile farther south it is the chloritic schists that appear here, the mica having been replaced by it. A line of hills may be followed quite near the river from the bend to the steam sawmill. Opposite the first island there is a cut in the chloritic rocks along the railroad, only a few feet from a hornblende lower down considerably disjointed. The adjacent hill by the turn of the road to Norwich village is a breccia of the chloritic group.

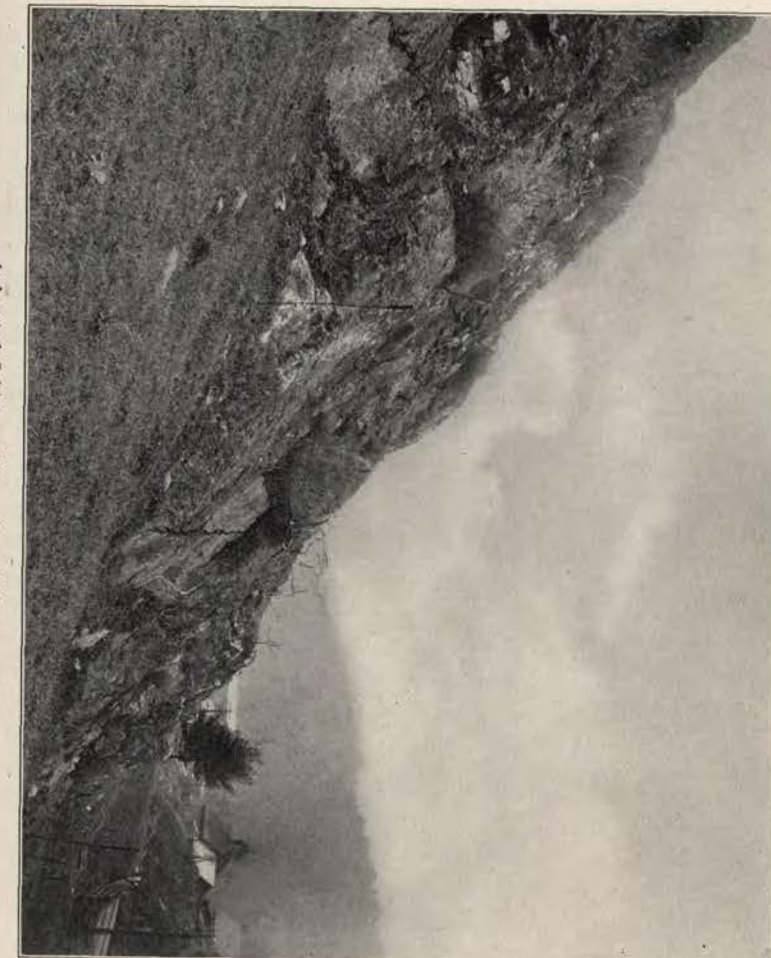
This hill rises two hundred feet from the railroad and has resisted erosion because of its induration, brought about by its contact with the igneous amphibolite. It is epidotic and sometimes resembles serpentine. In Plate XXVII the left hand side is the indurated rock of the hill, the railroad has cut through a greenish disintegrating hornstone, while the hornblende lies between the houses and the river. The observer is looking northerly.

Among the rocks of the hill is red quartz, common among the stones of the esker and once mistaken for the red sandrock of Burlington. The hornblende makes a point on the west side of the river and the folia have been broken considerably, being both vertical and dipping under the sawmill 80° N. 60° W., and dipping 60° N. 60° W. at the extreme point. Another exposure of a hard hornstone-like breccia may be seen just above the Ledyard bridge on the west side, two or three feet above the water and used sometimes as a pier for landing from boats. It has remained while the hornblende has fallen away.

Following the west bank further south we come to the Narrows opposite Negro Island. The island is altogether hornblende and the argillo-chloritic rocks opposite represent the altered material. As above, there is a pier here for landing, while only a few feet back from the river the effect of the heated mass ceased to have any influence.

From the Poor House to the Narrows the hornblende has been the same, but it came in contact first with the Coös mica schist, then the chloritic rocks, and lastly with what is conceived to be the narrower band of argillite shown on the map for a distance of two miles in length to the west of the bend at Lovelands. The plane of contact cannot be called a line of unconformity because the hornblende is not stratified rock; it is to be considered rather as a faulted scarp. The length of this plane that has been so carefully scrutinized is about five miles.

PLATE XXVII.



Indurated Schists. Steam Saw Mill, Norwich.

GRANITE.

There is an area of foliated granite in Hanover and Lebanon which has been called gneiss by many observers. I myself in early days found it to have a concentric structure, the core of which is porphyritic, encircled by protogene and capped by feldspathic mica schist.

Now it seems clearly to be a batholite with a foliation somewhat concentric and the upper layer in the adjacent Coös schist altered by contact, and the thermal influences working outwardly from the interior heated mass. Certain portions of it contain inclusions or fragments of the adjacent mica schist, which fact proves, first, the igneous character of the interior and, secondly, its age later than the schists included within it. There were extrusions from it into the south and southwest that are much like porphyries, accompanied by the formation of cupreous veins. The granite itself has long been known as an excellent building stone, being extensively quarried in Lebanon.

A study of the slabs used for doorsteps, platforms, window sills, etc., reveals many excellent examples of the inclusions.

Doctors G. W. Hawes and A. A. Julien have called the rock protogene. Prof. J. P. Iddings in a full description of the Lebanon stone (Bulletin 150, U. S. G. S.) calls it epidote-mica-gneiss. The following is a part of his statement:

"It is in fact an epidote-mica-gneiss according to present classification. It consists of relatively large, irregular crystals of microcline with small grains of quartz, in aggregate equalling the feldspar in bulk, besides brown biotite in aggregates of small plates, variable amount of colorless muscovite, and much epidote in aggregates of microscopic crystals. Subordinate minerals, occurring in relatively small amounts, are apatite tourmaline, allanite zircon, possibly sphene, and occasionally, green mica or chlorite, and rarely calcite. The rock is quite fresh and undecomposed, judging from the condition of the brown biotite. The epidote is grouped in aggregations with quartz and sometimes with muscovite, or is scattered in various sized crystals and grains through the microcline, but there are no remains or other evidence of any ferro-magnesian mineral more or less altered, from which it could have been in part derived. It appears as a primary constituent."

The microcline has a varied structure. The quartz forms irregu-

Brandon lignite. Though obliged to change the character of our studies, we find a compensation in the many interesting features of our history, brought to light by investigating the markings on the rocks and the deposits of earth transported in various ways.

Perhaps we may as well commence our story with some description of this wide sheet of till or ground moraine formerly spoken of as drift. The familiar expression hardpan will convey to people generally what this deposit is—a compact assemblage of materials without structure, but when dissected carefully found to be made of stones that must have been transported in particular directions, and divisible into two parts. The lower portion contains stones that have been transported great distances, are scratched according to method (glaciated), are of a bluish cast and very compact. The upper portion carries rough stones not glaciated, such as have come only short distances, the material is loose and of a reddish brown color. Plate XXVIII represents an excavation in this till upon Bragg's Brook, in Norwich, nearly a hundred feet high, kept fresh by the stream of water at its base. The absence of stratification is very apparent. The stones that are in the lower portion are recognized as having been derived, some of them, from a distance of forty miles. None of them are very large and the substance in which they are imbedded is a clay, very plastic when wet and evidently made by the pulverization of the slates and schists of the neighborhood and retaining its original color. Many prefer the name boulder clay to till for this portion. The upper reddish part may be only a strip of light color beneath the turf, and it has all the characteristics mentioned above. As the stream has been wearing down this bluff ever since the date of its accumulation, it is not difficult to believe that the valley was once filled with it from edge to edge on the top.

Our view of the origin of the till is that it is the ground moraine of the continental glacier, that it was crowded along beneath the ice generally, and for that reason the stones are of small size. The compactness is due to the pressure exerted by the weight of the ice, probably a mile in thickness. When the ice had been melted the pressure was removed and the upper portion consisted only of the debris that was in and upon the ice, which is confessedly the latest material brought, and falling through the water rests upon the compact mass and the fragments lie in stable equilibrium, unlike the stones beneath, which have been forced into unnatural positions.

The water rusts the stones and consequently this upper till is of a reddish brown color. In other words, the iron in the lower part is ferrous, in the upper part ferric. No doubt oxidation may be produced by the natural seepage of the water into the hardpan. That process cannot explain the roughness of the erratics and their derivation from localities near at hand. If one should now climb to the top of this hill, he would find a broad, smooth surface fitted for tillage, extending indefinitely to the northwest. The original dissected surface has been evened up by the ice acting as a gigantic scraper, and this feature is common over the whole quadrangle.

Let us look more carefully at this sheet of till as it rests on the south side of the valley of White River, through the central part of Hartford. Low down the edge is bluff-like because of erosion, higher up there is the same smooth surface extending to the crest of the ridge—all of this same till—and quite free from erratics. Plate XXIX represents a bluff of it exposed like that in Plate XXVIII by erosion at its base. It is at Centerville on the south side of the river, and at the mouth of a small stream draining the hillside from the Woodstock railroad and the western carriage road to Quechee village. Here may be found stones consisting of the red sandrock of Burlington, that have traveled about sixty miles. These were not seen on Bragg's Brook, because the direct line of the glacial current did not extend so far north. White River Valley is the most northern point which these red stones fell upon, and they may be found in greater or less abundance all the way from Centerville to Massachusetts. The best locality I have seen for them is at the deep railroad cut between Hartford and Quechee, which corresponds in structure to what has been exhibited in Plates XXVIII and XXIX.

The level nature of the surface of the till is well shown just opposite Centerville, where two houses are located at the altitude of 627 feet, 267 above the river. This flat is the top of the till exposed in Plate XXIX, so that the thickness of the sheet itself may be stated at something rising 200 feet. Its width along the Quechee road is a quarter of a mile where it has been cut through. This is an average section of the dimensions of this till sheet along the south side of White River. Looking at it from a proper vantage point this smooth, even surface may be seen to extend up to the crest of the ridge and two conclusions may be drawn respecting it; first, the leveling down was effected by ice, and, secondly, the movement was subsequent to that which left the ground moraine. This point may be better appreciated by the discovery that glaciated stones in the surface of the

PLATE XXIX.

Excavation in Till, Centerville, Hartford till have been scratched by this later movement. On the afternoon of June 23, 1892, there was a thunder storm which washed out the Trescott road east of the village of Hanover and cut into the esker by the Ledyard bridge more than has been effected during forty years of ordinary wear. That exposure brought to light stones that had been imbedded in the till of Balch Hill, having two sorts of striæ upon them, first, those pointing southeasterly, evidently made by the normal deposition in the till; secondly, inferior ones upon the surface with a course of south or S. 10° W. These stones seem to have held in place by the compactness of the till, while the movement down the valley carved out the additional lines.

Such a view will explain the phenomenon occasionally seen of two sets of striæ upon boulders. There is besides the consideration that large erratics often rest upon the till, but are of later origin.

I have not had the opportunity to demonstrate the truth of this view, but have found other stones imbedded in the surface of the till that are explicable in the same way, and we may for the present treat it as a working hypothesis till something better is discovered.

MORAINES.

Besides the ground moraine, our field of study shows us examples of the moraines of recession, if not some that are true terminals. Plate XXX shows an interesting accumulation of moraines near the Birch schoolhouse, in the west edge of Hartford on the height of land between the White and Ottaquechee rivers.

Something related to these piles of debris may be seen at almost every one of the cols between the larger streams.

One such may be seen east of Vail ridge in Pomfret. The following are examples of hummocks of till, moraine-like, in various localities: West of the Poor Farm, Norwich, and south towards the bend in the river; the valley through New Boston as far as Schoolhouse No. 17, west of Meeting-House Hill; the southwest part of Thetford; this material when the ice melted constituted the high terraces about Union village; the north end of Farnum Hill, Lebanon, and from Scytheville south between Farnum and Storrs' hills; the northwest part of Plainfield. There is a notable thickness of till through which Dimick Brook has cut its way for more than a mile, south of West Hartford. There is a suggestion of a terminal moraine coming nearly to the Connecticut in West Lebanon. Also an absence of modified drift to the west of Governor's Hill near the northwest corner of Hartland. One of the features of a terminal moraine is the presence of an immense pile of sand that has been washed from it.

Such is the case here, only a considerable portion of the stratified material has come from the tributary rather than the main stream. Well defined moraines connected with the edge of the great ice sheet have not yet been worked out in the vicinity of our field of labor; one may be looked for a few miles west of Ascutney and another along the lower Ammonoosuc.

STRIAE OBSERVED, MOSTLY COMPASS COURSES.

Cited from the New Hampshire Report.

Norwich, E. of S. H. No. 2, below Dutton's	S.
D. H. Bragg's, District No. 2	S.
Griggs' Hill	S. 8° E.
Windsor, top of Mt. Ascutney	S. 20° W. and S. 80° E.
Three-quarters down	S. 10° E.
At mill dam near Windsor	S. 30° E.

Observed for this Report.

Hanover, N. H., hill S. E. from Etna	S. 40° E., S. 20° E., S. 10° E. Near each other.
Above copper mine, Rudsboro	S. 20° E.
East of I. Fellows'	S. 10° W.
And numerous for a mile to the north.	
S. H. west of Moose Mountain	S. 8° E.
C. Swett	S.
In S. E. Hanover	S. 40° E. x S. 10° W.
Below J. Sweet's	S. 30° E.
Farther south, near I Camp	S. 20° W.
West side Velvet Rocks	S. 20° W.
Velvet rocks, top	S. 20° W.
Pinneo Hill, top	S. 10° W., better to the south S. 20° W.
West of Pinneo Hill, little valley	S. 20° W.
Hill to the west	S.
Near Poor Farm	S. 20° W.
Top of Lord's Hill	S. 20° W.
West base Prex Garden	S. 15° W.

Two miles north of Dartmouth College . . . . S. 20° W.
Negro Island. S. 20° W.
Top of Mt. Tug, Lebanon. . . . . S. 6° W. and S. 30° E.
Farther west. . . . . S. 35° E. in spaces between S. 8° W., S. 10° W.
For one mile to north, average. . . . . . S. 30° E. and S. 10° W.
At Kinnes. . . . . S. 30° E. and S. 10° W.
Schoolhouse (now gone) . . . . S. 40° E., S. 10° W. Specially described in text.
One mile north. . . . . S. E. in protected area.
D. E. Dudley. S. 30° E. and S. 10° W.
Hill south. . . . . S. 10° and 20° W.
Hon. J. Ross. S. 10° W.
Old mill site and quarry south Mink Brook . . . . S. 10° W.
Top hill, south side, Mink Brook. . . . S. 20° W.
S. E. side in quartz. . . . . S. and S. 30° W.
Spencer Hill. . . . . S. 20° W.
J. C. Childs'. S. 20° W.
N. W. part of town. . . . . S. 25° W.
T. Smith's on Ct. River. . . . . S. 20° W.
Top of Woodward's Hill. . . . . S. 20° W.
F. D. Slade. . . . . S. 5° W.
Lebanon, north end Farnum Hill. . . . . . S. 20° W.
South end, Farnum Hill. . . . . S. 17° W.
South side Mt. Tug. . . . . S.
Near top of Craft's Hill. . . . . S. 10° W.
Top Fay Hill. S. 10° W. and S. 10° E.
Allen Hill. . . . . S. 15° E.
Moose Mountain. . . . . S. 10° W.
Prospect Street, village Lebanon. . . . S. 8° E.
Norwich, Hill west of steam sawmill. . . S. 20° W.
Town Farm. . . . . S. 10° W.
Near Schoolhouse 20 and on hill west S. 10° W.
Hilltop east from soapstone. . . . . S. 10° W.
From here to Conn. River numerous examples . . . . S. 20° W.
Gile Hill. . . . . S. to S. 10°, W. and S. 40° E.

The eastern limit of the Connecticut glacier was very sharply defined upon the highlands above 1,500 feet, beginning with Moosilauke, eastern Hanover, Cardigan, Moose and Grantham mountains, and the whole Piedmont country to the eastward. There is no exception to this rule. On the west side the division ridges are not so high and have mostly lost the striæ once prevalent, both by actual chiseling and because the striæ were not retained upon the easily disintegrating ledges. Our observations give the southeasterly courses upon Wright's Mountain in Bradford, Potato Hill in Thetford, Gile Hill, Griggs Mountain and others in Norwich, Sprague and Hurricane Hills in Hartford north of the village and south of Centertown, the southwest part of Hartland and Mount Ascutney, for what may be called the west rim of the Connecticut glacier. The southerly courses cover nearly every rock exposure between the borders. Upon elevated land in the southeast part of Hanover for a linear distance of nearly three miles between Hayes Hill and Mt. Tug in Lebanon there is a magnificent display of the two sets of striæ, the rocks being particularly favorable for their preservation. Commencing with S. 10° W. in the low ground at East Lebanon, 800 feet, the same course is apparent on the south slope of Mt. Tug. At its summit, 1,500 feet, both S. 6° W. and S. 30° E. were observed.

Farther west and for a mile northerly, upon a ridge of the same elevation, the general direction is S. 10° W., interspersed with patches of S. 35° E. The finest exhibitions are near the cross-roads where a schoolhouse once stood. The same large ledge shows both the sets of striæ, the more southwesterly one lying upon the lee side of the ledge planed down with the S. 10° W. set. Within a radius of a quarter of a mile several other examples may be seen, equally good. The rock is argillite. Where two lines of striæ meet, the line of junction resembles the beveled edge of certain crystals.

In this vicinity, 1,500 feet, and also upon Mt. Fay to the west, at a slightly less altitude, there are many examples of remnants of the older S. E. course that have been spared by the later erosion. These patches are from one to two inches deeper than the adjacent planation and rough edges. Upon Fay Hill there are also fine examples of the "chatter marks," where chips of granite have been cut out by the graving tool. The elevated region of Hayes Hill is separated from Moose Mountain by a deep valley.

A locality of interest is on the hill west of Mascoma Lake, Enfield. Starting from near the Shaker settlement, altitude 800 feet, there is

the course S. 10° E., the only one seen on the east side. At the top, 1,600 feet, the direction is south. Lower down, S. to S. 10° W., in the lee of a planation of S. 30° E., upon a very durable conglomerate, altitude 1,200–1,300 feet. Here the older set were preserved because of the superior hardness of the rock.

The Moose Mountain range from the northwest corner of Enfield to near the north line of Hanover, present us mostly illustrations of the S. E. course. About the village of Enfield, the courses S. 21° E. and S. 24° E. are reported, elevation 800 feet. At the beginning of the higher land the course is S. 9° E. and at its base near the Enfield reservoir it is about S. 19° E. About a mile into Hanover the knife edge ridge of quartzite has been cut by a dike of diabase six to eight feet in width. Low down on the west flank the course is S. 5° W. Nearly two miles beyond the dike the striæ are S. 15° E. near the top. The following courses occur at intervals in going north: S. 25° E., S. 15° E., S. 40° E., S. 45 E., with a few stragglers S. 70° E., S. 30° E. This brings us to the lowest depression in the range midway from the south line to the old road over the mountain, where the ruins of farmhouses are visible, and where it is still possible to drive in a buggy from the east to the west part of the town, altitude 1,800 feet.

The courses S. 12° E. and S. 15° E. have been noted here. The character of the rock changes here from quartzite to protogene, and the striæ are not preserved upon it. There are two domes beyond of equal height, 2,326 feet. Between them is the line of the old carriage road. To the north there are several examples of the course, S. 25° E. One old observation is supposed to have been taken near the trigonometrical station at the north dome. These many observations amply justify the generalization that the southeasterly course is the dominant one for this stretch of eight miles along the crest of Moose Mountain.

Gile Hill, Norwich, 1,917 feet, is the highest eminence between the Pompanoosuc and White rivers, and, therefore, is an exposed point where the older course would be looked for. Upon the east side there are many examples of the striæ running from S. to S. 10° W., and the dome at the summit has been planed down by the same movement. The weathering of the whole has been excessive so that it is difficult to find anything but the general smoothing, and this difficulty increases every year. There are many localities in general that suffer from this decomposition where the courses could easily be seen thirty years ago.

Upon examining the steep southerly side of the S. W. course upon Gile Hill, at my last visit, I was able to detect obscure lines and furrows of glaciation with a direction of S. 40° E. Had the later movement been more nearly in the direction of the earlier one, even the scant remnant now visible would have been wanting.

Potato Hill is the knob west of North Thetford, 1,600 feet elevation. Upon the east slope about the base of the hill the striæ run S. 15°–20° W. Higher up there were noted successively the directions S. 10° W., S. 16° W., S. 10° W., and on the very summit a smoothing in agreement with the ones mentioned. Upon descending the west side the course was S. 5° W., 1,360 feet, and S. 8° W. still lower, but at several places there were remnants of the older course, S. 30° E. and S. 20° E., where they had been protected.

In Bradford may be seen the highest of all the mountains on the west side of the Connecticut. I think it must exceed 1,500 feet, the altitude usually assigned to it. I reached it from East Corinth and found striæ S. 10° W. in northwest corner of S. H. Dist. No. 4. Nearer the top the course is S. 20° E., on mica schist, but on the crest of the hill in the road it is S. 10° W. On the summit of Wright's Mountain the striæ run S. 20° E. Every ledge upon the north side is embossed and striated. There were some very distinct markings between the road and the summit, S. 5° W. It would not be worth while to extend the list of observed striæ in this part of Orange County, though I have some interesting facts concerning the glacial history of this region.

Mount Ascutney, just south of our quadrangle, might be appealed to for its record of glaciation. It may be regarded as a measuring pole situated in the midst of the Connecticut glacier, and so far as the later markings can be determined, it should be possible to secure satisfactory results. There are two difficulties in the way of observation: First, the peak is heavily wooded, so that the ledges are concealed by vegetable growth; and, second, where the rocks are exposed they have been speedily disintegrated. Several observations, however, may be relied upon as truthful. On the summit striæ were early recognized with an easterly course. Three hundred feet below there are striæ resting upon a jointed wall inclined northerly with a course N. 80° E., and pointing down towards the south part of Cornish. There are others running S. 20° W. About two-thirds of the way

PLATE XXXIII.

Material of Terrace, Quechee Fells Farm.

down the striæ had the direction S. 10° E. Upon a later trip I found the easterly course near the top S. 70° E., two hundred feet below the summit, and the directions S. 10°-20° W. at several places near the path. Near the lower end of the path near Dudley's, at an old limekiln, the course was easterly. Both courses have, therefore, been noted on this mountain.

An illustration of both these courses may be derived from a study of the directions in which boulders have been carried from this mountain. The rocks are so peculiar petrographically that they are easily recognized. In Claremont these rocks are very abundant, having been carried about eight miles in a southeast direction. In Surry, N. H., Butler's rock, a block 20 feet long and 12 feet high, has traveled 27 miles in a direction S. 20° E. to reach its present abiding place. Other examples are in Keene, 35 miles in the direction S. 8° E.; the west base of Mount Monadnock, 42 miles S. 20° E.; and many in the towns of Alstead, Langdon, Gilsum, Sullivan, Walpole, Westmoreland and Hinsdale. The one that has travelled the greatest distance was picked up in Bernardston, Mass., 50 miles in the direction S. 4° W. Others of large size have been noted on the Vermont side of the Connecticut in Weathersfield, Springfield. The conclusions from this class of facts, therefore, agrees with the one learned from the striation, that there has been an ice movement southeast and southerly from Mount Ascutney. As the southeasterly striæ are not very abundant high up on the mountain, the great profusion of the boulders in Claremont proves that the movement was an important one. It is conceivable that the stones might have started in a southeasterly direction and were perhaps abandoned, but were picked up by the later southerly movement. Such a path would be curved were it possible to mark it out, while we see only the general result and conceive the movement to have been made in a right line. The lines correspond to radii having Mt. Ascutney for the central point, diverging 49 degrees.

NOTE.—Since writing the above Mr. Luther P. Eaton of Peterborough, N. H., informs me that he has found these Ascutney boulders in the northwest part of Peterborough, Harrisville, Hancock and Nelson, thus considerably extending the area of their dispersion.

THE MOVEMENT DOWN THE CONNECTICUT VALLEY.

The whole quadrangle was covered by the Connecticut Valley movement. Wherever the rock has been enduring the indications of the movement have been preserved in the striation, and in a few cases by the transportation of fragments, which are the same with those that came down the esker deposit subjected to a later washing. Owing to the situation anything brought down by the southeast course may appear as a pebble in the gravel, so that it is to be expected to find fragments of the serpentines and steatites of central Vermont, the granites of Barre, the red sandrock of Burlington, and the Cambrian quartzites of the west side of the Green Mountains.

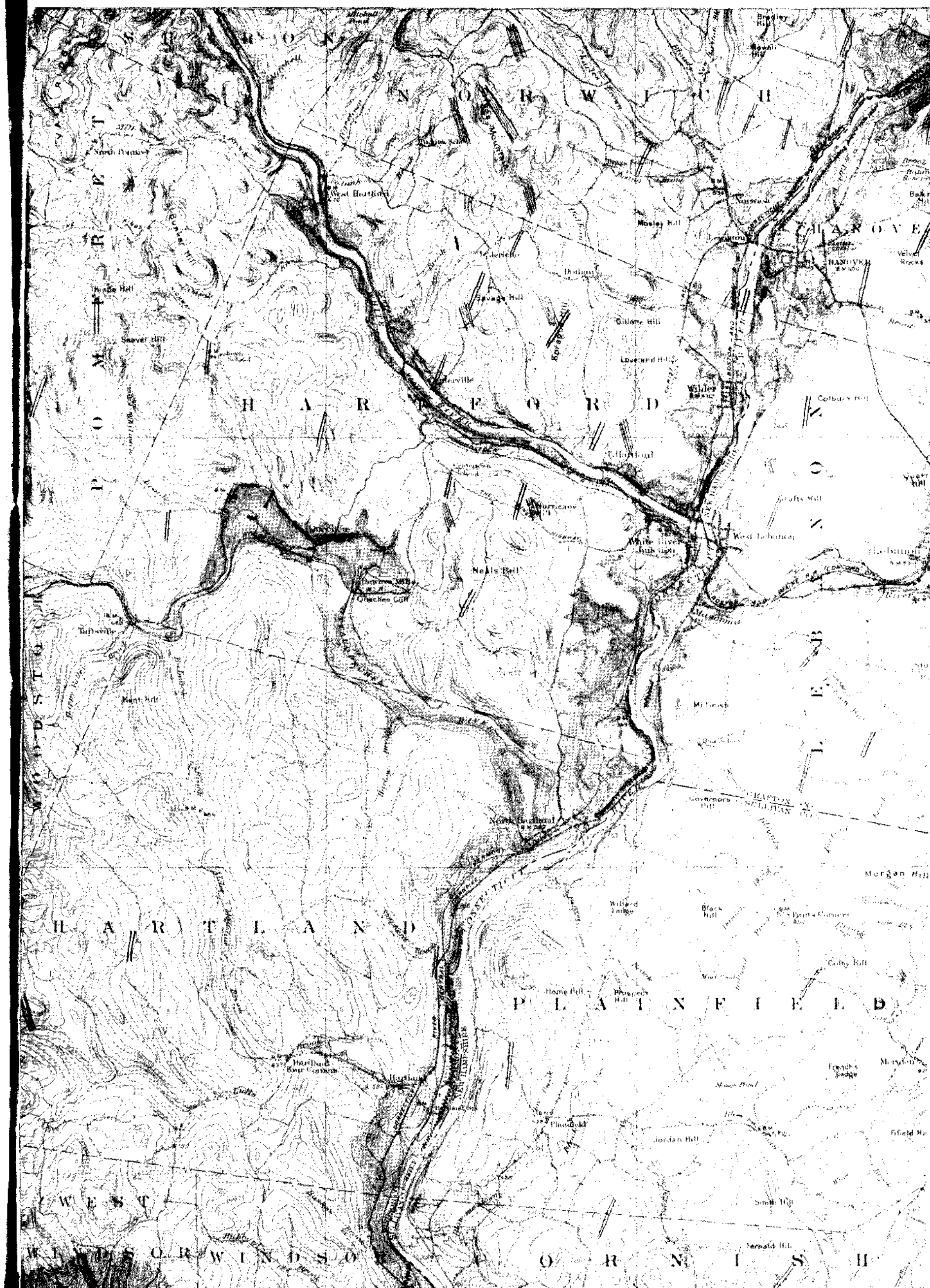
In distinction from these there are pebbles of granite and porphyry that have made their way from the White Mountains. These occupy exactly the course taken by the Connecticut movement. It is rare to find any sample of stone that has come from the east side of the valley among the pebbles. Such as will be mentioned as of glacial transportation have been moved in the very latest stage of the glaciation.

The observations illustrating this Connecticut movement are more numerous than all the others combined, but it is more important to present the others so as to appreciate the diversity of glacial action. Many of the examples known have been omitted in the printing of this report. In some future report it will be proper to mark upon a map the exact position of every example of this striation.

MAP SHOWING GLACIAL FEATURES.

Plate XXIXa.

A few of the glacial features of the quadrangle are upon the map shown as Plate XXIXa. The modified drift of the Connecticut, White, Mascoma and Ottaquechee rivers is represented as a whole. The principal esker follows the Connecticut from the northern part of Norwich to Windsor, the smaller esker in Hartford belongs to the local glacier of the Ottaquechee River, both shown by zigzag lines. All the examples so far observed of the southeasterly system of striæ are shown where they belong by parallel lines situated at their proper angle with reference to the points of the compass. All the rest of the area has been traversed by the course running S. to S. 20° W., shown by parallel lines, and of these only a few are represented. Others may be located by reference to the tables of striæ. It is worthy of note that they are to be seen upon the



ap showing the Location of the Modified Drift, the Eskers, the Remnants of the South East Stri
a few of the Striae running S. 10° W. and the Quechee Glacial Lake.

PLATE XXXII.

Vegetable Seams in Clay, Lebanon, N H

top of Thistle Hill and most other elevated places, but there is a scarcity over the areas of Conway schist, due partly to insufficient search and partly to easy disintegration of the rock. Instead of representing all the features of the Quechee glacier, only the area occupied by a body of fresh water as soon as the ice melted is shown, coupled with the copious deposits of sand carried through the spillway or overflow from the glacial lake. These deposits merge into the higher flood plain of the Connecticut at North Hartland. No attempt is made to represent what must have been local ice movements elsewhere in the quadrangle. They are mentioned in the text.

INSTANCES OF MOVEMENT FROM TRIBUTARY VALLEYS.

The picture is now plainly in mind of a broad glacier sliding down the main valley. If this is a fact, there should also be tongues of ice joining the main mass from the tributary valleys on both sides. Facts illustrating such action are to be found in the valley leading to the Connecticut from the Hanover reservoir, down a small valley in Norwich opposite the first island, down Bragg's Brook, in the same town, down Mink Brook in Hanover, boulders of protogene transported westerly from Colburn and Crafts hills in Lebanon, the same material transported from Quarry Hill in Lebanon to Farnum Hill, the White and Ottaquechee local glaciers down the valleys of the same name.

The best evidence of the movement from the Hanover reservoir consists of striæ upon the hornblende rock at the mouth of the tributary about two miles north of Dartmouth College, pointing N. 60° W.

The small valley west of the first island shows striæ pointing towards the Connecticut in the direction of S. 40° E. One of the marks is a groove a foot wide chiseled out of the slate. Several observations have been made of the striæ down Bragg's Brook, the most marked being directed S. 70° E. Mink Brook east of Etna spreads out very broadly upon the west flank of Moose Mountain, so there was a fine gathering of ice ready to be pushed down through the narrow valley. As a result there are many recent striations pointing southwesterly east of the Baptist Church on the slates. In the lower part of its course there are moraines of large blocks crossing the valley at several places. Where the valley has made a sharp turn these erratics have been left in the angle of the curve. One of the blocks belonging to this series measures 30 x 42 x 15 feet and contains 18,900 cubic feet, weighing 1,600 tons. A good terminal moraine of these blocks crosses the brook near the turn of the road to Lebanon, about a mile southeast of the college.

Both ends are in plain sight, while the central part has been covered by clay. The granite area terminates a mile east of the river, but blocks of it are found lower down, and in particular, one of considerable size upon Chase Island. The transportation of these granite boulders has been more marked in Lebanon. Many large blocks of them may be found upon the flanks of Colburn and Crafts hills. As the transportation has been to the west it cannot be explained by the action of the ordinary movements. The action was most pronounced which carried the granite from Quarry Hill, strewing blocks all over the region to the southwest and leaving some of them upon the north summit of Farnum Hill. There are striæ there S. 20° W. made at the time of this transportation.

This granite has also been transported by the southeast current to Allen Hill, to the thick deposits of till spread along the brook by the east line of Lebanon and all over the township. The angular distances from the source are greater than in the case cited above of the dispersion of boulders from Mt. Ascutney.

The movement down White River has left fewer traces of its presence. About half a mile west of Hartford there are striæ upon the slate running S. 20° E., from only fifteen to twenty feet above the river. There are others near the fair grounds.

QUECHEE LOCAL GLACIER.

The most important of these local movements is the one that occupied the valley of the Ottaquechee. Its existence was detected as far back as 1854, and it was very briefly described in the report of 1861. It is worthy of note that it was described by one who believed in the agency of icebergs accompanied by submergence to account for the ice age, but the agency of glacial action like that which had been examined in Switzerland was overwhelming and convincing. At least two branches of it high up on the Green Mountains are very plain. One came down from the northeast part of Plymouth. Both in Plymouth and Bridgewater the movement to the northeast is plainly indicated by the planation of the ledges. The other branch came from the deeply incised valley of the main river in Sherburne.

There was a large area well suited for the gathering of the ice about the head waters of the basin.

Near the east line of Bridgewater, my father describes a moraine considerably modified by water. Near an iron bridge crossing the river to a farmhouse in the west part of Woodstock, the north bank is covered by erratics which are properly a lateral moraine. At West Woodstock there is a terminal moraine just east of a broad area of low ground. Evidently the glacier had pushed forward here for a time and its end remained stationary, while the debris accumulated at its extremity. In the east part of the village of Woodstock there are many erratics running up the hill on the road to Hartland, which must have had a morainal origin.

After leaving Woodstock, the valley narrows, but widens again near Quechee. The new suggestions confirmatory of the existence of the glacier have been obtained from a study of phenomena observable below this point. There must have been a glacial lake occupying the area of the modified drift shown upon the map. Plate XXXVII shows the view from the north side of the great bend in the river, looking towards the sharp curve in the railroad. The river is in the foreground, and behind it is a broad meadow at two levels, three small terraces and a higher sand deposit beyond at great height. Thus there are six different terrace levels visible in this view. The maple tree stands upon an esker, made by the usual agencies producing such phenomena when the ice of the local glacier filled the valley.

Because of the need of proving the existence of this glacier, we may say here is a small typical esker in the midst of these terraces which must have been made either in the archway near the end of the ice of the local glacier, or in an open cut. Therefore, there must have been a glacier sliding down the valley below Woodstock. The wide, open valley must represent the space occupied by the glacier, as it impinged against the till to the north of the great bend. Plate XXXIII shows the coarseness of the material forming a very neat terrace not far from the esker, upon which Quechee Fells Farm is located. No one would have imagined the coarseness had not erosion disclosed it. Plate XXXV shows where this glacier rested near Dewey's Mills. The buildings show obscurely at the right of the picture under the railroad train seen to be in motion. The mill is at the beginning of the gulf. The railroad train runs over a plain of gravel that is a hundred feet higher than the low ground of the picture. The area of this plain is shown upon the contour from the village. They are believed to agree in altitude with those represented on Plate XXXVII, estimated to be respectively 10, 20, 40, 60 and 80 feet high. 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. None of these smaller terraces are to be found outside of the glacial lake area.

THE CONNECTICUT ESKER.

Our quadrangle contains the greater part of the famous esker extending from Thetford to Windsor and first understood by Dr. Warren Upham and described in the New Hampshire Report under the name of "kame." The present usage of geologists in regard to the terminology of these two classes of deposits was not fully understood in 1878. Dr. Upham followed the leading of Dr. James Geikie. As this ridge has been so thoroughly described it is not necessary to repeat what has been written already, but to refer to the map where the course of the ridge has been portrayed.

Some suggestions have come as to the relations of this esker to the till. No section has been discovered as yet where the till and the gravel meet each other. Excavations in Hanover look as if the esker were underlaid by an early clay, which has been crumpled by some unknown force, perhaps the motion of the ice. This clay appears in Girl Brook, at the cut for a sewer near the Mary Hitchcock Hospital, near the Ledyard bridge and between the houses of Professors Patten and Dow.

There seems to have been a system of drainage in the village of Hanover prior to the formation of the esker, interrupted by the deposition of the gravel. Thus an arborescent system of valleys converge at the cut by the Ledyard bridge. But their outlet was blocked by the incursion of the esker; for it would appear that the esker was once continuous from brink to brink above the present road which has been used only a little more than a century. The former crossing of the Connecticut was a mile higher up. The Honorable Daniel Blaisdell informed me that he saw a pine tree bridging this chasm when it had been cut down, the stump being on one side and the top on the other. If so, the cut could not have been very deep. This ancient system of drainage raises important questions which cannot be answered.

Plate XXXI shows the appearance of this esker as it has been excavated of late for road material near White River Junction.

The following is a list of the stones found in it:

Red and drab porphyry from the White Mountains.
Granites allied to those of Barre and other localities southeast from Montpelier.
Granite or protogene from Fairlee.
Diabases and diorites from the Chloritic Group.
Jasper from the same group.
Amphibolites from eastern Vermont.
Limestone from the Conway schist.
Coös mica schists and quartzites.
White quartz veinstone.
Augitic rock.
Blue Mountain granite.
Cambrian quartzite from the Green Mountains.
Hornblende schists of variable composition.
Epidotic hornblende.
Decayed limestone.
Decayed rocks stained by manganese.
Chloritic schists and sandstones.
Argillites.

It is an important omission that none of the protogene granite of the Hanover-Lebanon area has been found in the esker. This shows that nothing came into it from the east. The absence of serpentine is more likely to be accidental.

THE HIGHER FLOOD PLAIN.

Various expressions are appropriate for the extremely high mass of sand and clay brought down at the time of the melting of the ice. It may be the higher flood plain or the highest normal terrace, and both may be modified by the extra high accumulations brought down by tributaries where for special reasons the amount of water discharged by them was excessive.

We cannot say that the highest tributary delta represents the highest normal terrace. Thus there is thirty feet difference between the delta of Mink Brook where it touches the edge of the flood

Terraces below Queechee Village.

plain on the Lebanon road and the plain in the village. If the water of the Connecticut ever reached the higher level, it must have been only for a moment, as it were, and is not to be considered as the true height.

There is not time to consider a sand plain which appeared at a higher level than the highest terrace in Lebanon and Hartford. It reaches 560 feet east of Wilder, and on the hill west; also at the fair grounds and at the turn of the road southwest toward Farnum Hill, about a mile east of the electric power house of West Lebanon. These are somewhat connected with the dunes of Plainfield. It is worthy of note that the altitude of the high sand is the same as that of the delta of Mink Brook. The material of the flood plain in the west part of Lebanon and Hanover and across the river is a loamy sand often carrying claystones. It shows occasionally thin strata of a vegetable character, as if a season of growth, or possibly a time of freshet were indicated. Plate XXXII was taken to illustrate the presence of two of the layers. The locality is in the northwest part of Lebanon near the east edge of the plain, and the underlying till is also shown just at the top. Better exposures were seen later farther north, in one of which, in the Mink Brook Valley, seven of these peaty seams were counted. The phenomenon is a common one.

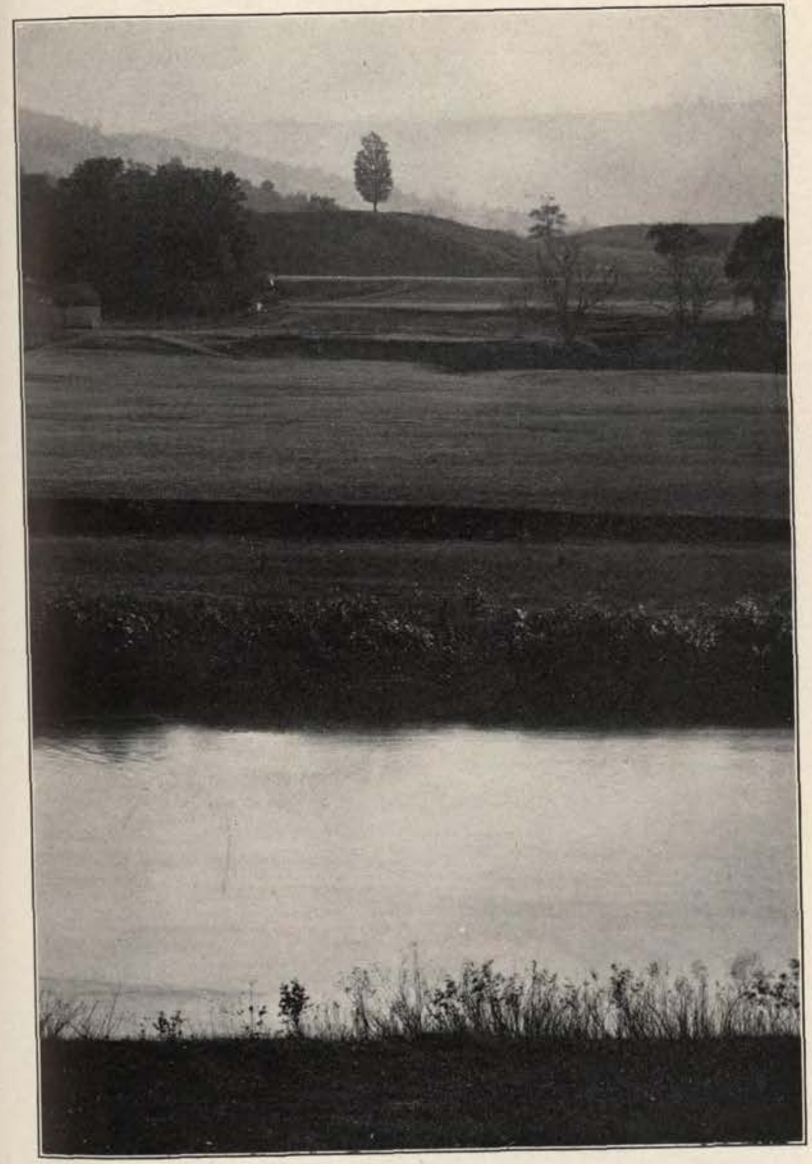
THE PROTECTION OF TERRACES.

It is only recently that we have arrived at a clear understanding of the reason why the lower terraces occur and why their number is variable. It is purely a local affair. The original high flood plain extended across the valley and the several lower terraces have been carved from it. Sometimes the entire mass has been removed by erosion where the current happened to be stronger than usual.

This appears to have been the case in the lower Coös meadows at Haverhill. Following the river to Hanover, about two miles north of the college, the high plain suddenly appears. Apparently this is due to the fact that the presence of the esker protected the silt from being worn away when the Connecticut changed its course and turned northwesterly across the esker. This ridge of gravel has maintained in its place the whole of the flood plain as far as Wilder: and it may be remarked incidentally that the original course of the river must have been beneath this protected plain, because the present stream runs over ledges at Wilder.

Borings into the silt have not reached the rock foundation along this old course in Hanover. Plate XXXIV illustrates the protection of a terrace at Hartford. The village is situated upon it, but the river would have washed away the foundation were it not for the presence of the ledges in the left-hand part of the view. The water impinged against the rock and could not wear it away and because the rock was preserved, the sand above it was also kept in its place, only, however, to the level of the rock.

Back of the village and farther east there is a higher terrace that represents the proper high flood plain, which must also have been kept from erosion by the ledges. Many other illustrations of this principle have been observed in the field and are not mentioned, as are not several other important matters, for want of time.



Esker, west of Queechee Village.

Stellae and Rabdoliths of the Genus Strephochetus.

HENRY M. SEELY.

In the Chazy rocks there occur various small rounded or nodular masses, some of which have been studied and found to be distinctly organic. Among these fossils is a form of calcispongia that from its structure of tangled thready character is generically known as *Strephochetus.*

This genus Strephochetus with its peculiar micostructure is found in all the three divisions of the Chazy formation, yet from modifications and manner of growth these forms so distinctly differ that they have been separated into well marked species. Of these species the middle Chazy contains the largest number. The first published species *Strephochetus ocellatus,* is from this division and to this form the following paragraphs apply.

The chief subject of earlier study was the peculiarities of structure of this form. Here attention is called to the portion left over after treating the little calcareous sponge with dilute acid.

Strephochetus thus treated leaves as a residue several ingredients. Though so low down in the geologic series of rocks it still retains a portion of organic matter. This appears in the solvent as dark colored corneous flocculi corresponding most probably to the epitheca of Prasopora. The undissolved silicious matter consists of very minute granular material, and another of much coarser granules having the appearance of broken grains of quartz, and these two other notable forms here treated, the star-like matter Stellae and the staff-like objects Rabdoliths.

It is the primary purpose of this article to set forth the results of observations on these two forms, Stellae and Rabdoliths.

A Stella, as one would easily conjecture, is a silicious hexactinalid. The simplest is of the six rayed snowflake form. This simple form however is rare. Others of greater and greater complexity occur, and the multiplication of rays goes on until it seems impossible to enumerate them.

Not only do the Stellae vary in the number of rays, but also in size. The most frequent magnitude is 0.5 mm., but specimens have been observed of twice this size, others are only half as large.

The Stellae are exceedingly fragile, the rays parting from the axis very readily, and then often aggregating in clusters. The individual rays are acicular in shape. This acicular character should be especially noted, as it is helpful in distinguishing the individual ray from the form next to be described. As seen through the microscope the Stellae are exquisitely beautiful; their transparency and fragility have thus far forbidden their complete photographic reproduction.

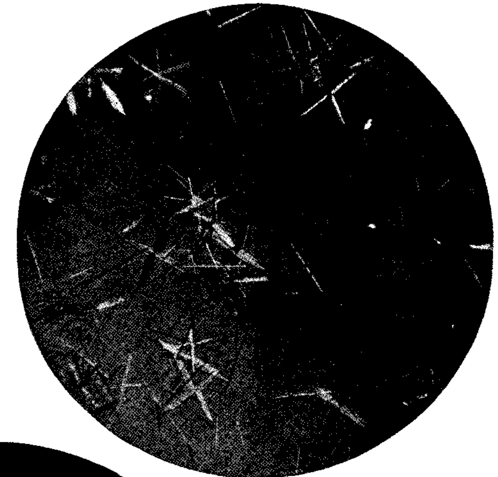
Rabdoliths may be recognized by their general staff-like character. They differ from the rays of Stellae by their greater length, their uniform diameter, and their blunt and often truncated ends. The length may be stated as 1 mm., although individuals occur only half as long, and then again very many others of twice or thrice this length. They can be seen by a slight enlargement, but their minute diameter prevents their easy recognition by the unaided eye.

The accompanying illustrations, Plate XXXVIII, will aid in acquiring an idea of the forms here described.

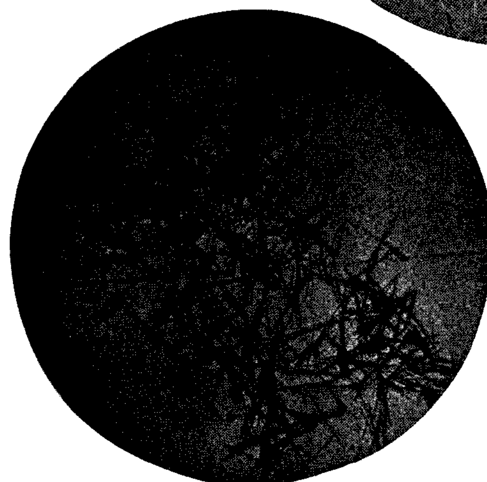
Further study will be necessary to determine in what other genera than Strephochetus, Stellae and Rabdoliths are to be found. Examination has gone far enough, however, to assure one that they occur in several and probably in many, some of these of near, others of distant, generic relationships.

The suggestion is offered that the organic origin of certain calcareous rocks, whose history has hitherto been uncertain, may be established by means of the presence of the Stellae and Rabdoliths herein described.

PLATE XXXVIII.



Stellae X 45 crossed Nickel.



Aggregated Rays broken from Stellae X 75.

Rabdoliths and Stellae X 45.

Preliminary Report on the Geology of Franklin County.

G. H. PERKINS.

Franklin County occupies the northwestern corner of the state. Consequently its northern border is also the Canadian border and its western border is part of the shore of Lake Champlain. As the Green Mountain range extends through the eastern portion, the surface there is often very rugged and the rocks are largely metamorphic or crystalline.

Thus far the work the Survey has been able to carry forward has been confined to the western border among the stratified rocks. While the geologist has visited numerous localities in this part of the county, mostly in company with Mr. G. E. Edson of St. Albans, who has for some years made a careful study of the strata in and about that place, most of the field work has been done by Mr. Edson. In the Report of 1904–6 a chapter by him on the geology of St. Albans was published with a small map. As will be seen on following pages, Mr. Edson has continued his explorations into Swanton and during the past two years has gone over its area and located the different terranes. Both Mr. Edson and myself have also done some work in Georgia, the town immediately south of St. Albans, and in Swanton, and Highgate on the north.

It is unnecessary to inform geologists that the rocks of much of the western part of Franklin County have long been under consideration, especially in the discussion of the Taconic question. Aside from this at one time much mooted subject, some of the beds of Swanton and Georgia, and their fossils, have been of great geological interest. For the most part fossils of any sort are not abundant in the rocks of the region, but there are some layers, or small areas, in which the fossils are numerous and well preserved. The beds are in many places much more fossiliferous than appears to a hasty investigator. For there are layers in which few or no traces of fossils can be found unless weathered portions can be obtained, and then it is found that the seemingly barren rock is full of fossils which have so exactly the characters of the rock mass that they are wholly invisible unless oxidation has changed the color and condition of both rock and fossil. The rocks of the county occur in great variety, there being sandstones, shales, limestones and conglomerate of different sorts in the western portion, and schists, slates, granites, serpentine, etc., in the eastern part.

It is not to be expected that geological terranes confine themselves within political boundaries, and the fact that the boundary between Canada and the United States crosses the formations which extend from Vermont northward into Canada makes the work of the Canadian geologists in this region doubly interesting.

While some of the views expressed forty years ago would not be put forward today, many of the conclusions expressed in the Geology of Canada, 1863, pp. 272–275 and 854–859, are as important as when first published. I shall, therefore, give the following quotation from Sir W. Logan's account of the geology of the region:

"It has been stated in a previous chapter that what has been called the Deschambault anticlinal, brings to the surface, between St. Dominique and Farnham, strata of the Trenton, the Birdseye and Black River, and the Chazy formations; the exposure being almost wholly confined to a comparatively narrow strip on the east side of the anticlinal axis. The distance between the two extreme exposures is about twenty-five miles and the bearing of the axis, in this distance, is about S. 15° W. If continued in the same direction for eighteen miles farther, it would reach Mississquoi Bay on Lake Champlain and run under the waters of this bay about three-quarters of a mile west of Phillipsburg. From this a gentle turn a little more southward would carry it in four miles farther, to the shore of the same bay, near the Franklin House at Highgate Springs, Vermont. At this spot, strata similar to those of St. Dominique are brought to the surface by an anticlinal, which may not improbably be a continuation of that of St. Dominique and Farnham.

"As already mentioned, the band of Trenton limestone running between these two places is only about a mile from an exposure of the Sillery division of the Quebec group, on the Barbue. The exposures of the Trenton band in this part reach farther south than those of the Chazy, and, approaching Farnham, their breadth gradually diminishes, until they terminate in a point not far from the Yamaska River. This arrangement would indicate a gentle slope on the crown of the anticlinal. This would probably bring in higher strata farther south, from beneath which the Trenton limestone would rise again in Mississquoi Bay, to join the exposures near Highgate Springs.

"The natural inference, unless fossils were found to contradict it, would be that on the axis of the anticline, between Farnham and Highgate Springs, we should find the Utica and Hudson River formations.

"The lowest rock brought to the surface on the anticlinal at Highgate Springs, is a dove-gray limestone, similar to that at St. Dominique. It occurs on what is considered the axis of the anticlinal, near a wharf and an old lime kiln, on the shore of the bay, less than half a mile northward from the Franklin House. It is associated with bands of brownish gray, buff-weathering dolomite, from one to three feet thick, and is flanked on both sides by greenish-gray, calcareous, fine grained sandstones. Those on the west side of the axis have a thickness of probably between fifty and a hundred feet, becoming at the top interstratified with greenish shale. No fossils have been found in the dove-gray limestone, but in the upper part of the sandstone there occur one or two undetermined species of trilobites, probably of the genus *Asaphus*. These sandstones are followed on each side by blackish, thin-bedded, shaly, nodular limestones, partially magnesian. They are fossiliferous, but the species do not appear to be numerous. Among the fossils met with on the east side are *Ptilodyctia fenestrata, Orthis platys* and *Ampyx halli,* all Chazy species. . . . The thickness of these shaly beds is not certain, but they probably exceed sixty feet.

"The shaly, nodular beds are followed on each side by about thirty feet of black, massive limestone. Southward from the limekiln these bands, which are about 300 paces apart, run parallel with one another for some distance inland, and then gradually curve around so near one another as to make it probable that they may join, not far beyond the spot where they have become concealed. Both bands hold masses of black chert; that on the west contains *Orthoceras recticameratum, O. anellum* and *O. allumetense,* while that on the east has *Columnaria alveolata, Stromatopora rugosa, Petraia profunda, Helicotoma planulata, Murchisonia perangulata,* and *Orthoceras bigsbyi,* leaving little doubt that these beds represent the Birdseye and Black River formations. These black calcareous bands are succeeded on each side by a series consisting chiefly of black, thin bedded, shaly, nodular limestones, interstratified occasionally with thicker beds of the same color. These strata on the west side appear to have a thickness of between 300 and 400 feet, and contain towards the middle about thirty feet of massive black limestone. They are highly fossiliferous and contain, among other species, *Stenopora fibrosa, S. petropolitana, Ptilodyctia acuta, Orthis lynx, Rhnyconella increbescens, Orthoceras strigatum, Calymene blumenbachii* and *Trinucleus concentricus*. On the west side of the axis these strata are followed by black, brittle shales, which occupy a breadth of about seventy yards, and reach to the margin of the bay. They are fossiliferous, but, having a cleavage independent of the bedding, it is difficult to obtain specimens. *Orthis testudinaria*, however, occurs in them in some abundance, and as there is no doubt that the limestones to the east of them belong to the Trenton, these black slates would appear to come into the place of the Utica formation. On the west side of the anticlinal, the strata have a more precipitous dip than on the east. The inclination on the former side appears to range from about seventy to ninety degrees, and it occasionally shows an inversion of the strata.

"Plunging under Lake Champlain in this attitude, the Trenton formation is not known to emerge again before approaching the opposite side of the lake. It is probable that the shales which fill a great part of the interval between these two outcrops, may belong to the Utica and Hudson River formations, as these are known to occupy a considerable part of the promontory separating Mississquoi Bay from the Richlieu River.

"On the east side of the anticlinal, the inclination of the strata does not appear to exceed forty-five degrees, and to the west of the Franklin House a subordinate undulation repeats the Birdseye and Black River limestone and carries the Trenton farther east. After a short interval of concealment to the east of the House, the latter formation rises again near the mineral spring with an attitude not far removed from vertical. This is very probably a final outcrop, as some magnesian strata, which seem to belong to the Quebec group, appear not much more than a quarter of a mile beyond. The eastern outcrop of the Birdseye and Black River limestone, connected with the subordinate undulation, is traceable northward to the margin of the bay, about a quarter of a mile from the axis of the anticlinal, where its dip becomes S. 30° E., increasing to 39°."

In a later part of the same volume the author, Sir William Logan, adds to his account of the geology of that part of Franklin County which he had investigated, the following:

"The relation of the strata on the western and eastern sides of the great fault which runs between them, as well as of those on the opposite sides of its continuation at Highgate Springs, has already been given. The strata on the west side of the fault at the latter place belong to the Chazy, the Birdseye, the Black River, the Trenton and the Utica formations. The Trenton at its final outcrop has a western dip, and there would be room in the covered space between it and the Quebec group for the Birdseye and Black River formations, as well as for the Chazy and the dove-gray limestone which may be a part of it. (A diagram showing the relative position of these formations is given.) At Smith's lime works, about eight miles southward of Highgate Springs, these formations (probably the east side of another synclinal) become inverted. . . .

"Between the high road and the railway from St. Albans to Swanton and about a mile and a half northward from Smith's lime works, there occurs another exposure of the rocks of division E. (Chazy). The dove-gray limestone approaches to within 240 yards of the high road and shows a breadth of about the same measure, with a dip of 30°–80° E. The west side of this mass, in its strike to the south would come close upon the east side of an exposure of the sandstone, which with a dip in the same direction as that of the limestone has a breadth of 220 yards, with an inclination of from 35°–55°. This would give it greater thickness than where seen elsewhere, but its apparent volume may possibly be increased by disturbances.

"On the west side it becomes interstratified with the black limestone, which terminates the exposure and approaches to within about 120 yards of the railway. These masses are precisely in the strike of those at the lime works and a continuation of the strata in the same direction would carry them in less than a mile across the road over the flat land between the red strata of the Potsdam and the Mississquoi bridge southeast of Swanton. Less than another mile in the same direction would bring us to a development of the dove-gray limestone about a mile east from Swanton on the road to Highgate Falls.

"The strata of this exposure, which has a length of about 400 yards, and a breadth of about 200, are arranged in the form of a trough converging northward, the dip on the west side being about

S. 72° E., varying from 55° to 80°, and on the east S. 60° (40°–85°).

"But to the southeast of this there is another and a very considerable exposure of dove-gray limestone between Swanton and the Mississquoi bridge already mentioned. The area which it occupies has a length of about 1,200 yards, terminating southeastwardly at the margin of the river, and a breadth of 700 yards. The general strike of this mass appears to be about N. 15° W., which would carry it a little to the westward of the exposure on the road to Highgate Falls. The general dip of the strata is to the eastward; the angles of inclination, as ascertained on the east and west sides of it, vary from 13°–25°, but in the intermediate part there are two undulations, which serve to diminish the average rate.

"This area has very probably a farther extension northward and may join the west side of the one just described as occurring more to the north, the strike of that side of the more northern exposure being directed towards it. Its position and attitude would seem to indicate that it is on the western side of a trough, of which the exposures of dove-gray limestone farther south are on the eastern and more precipitous or overturn side, and that these masses have above them in the middle, a conforming mass of the sandstone and black limestone.

"To the southward of Smith's limekiln the same series of strata occur at the lime works of Mr. Rich. They still present the same inverted attitude and Professor Emmons states that orthoceras is here met with in the dove-gray limestone. Still farther southward, about a mile beyond Stevens brook the dove-gray limestone is seen close against the red strata of the Potsdam group, and about a quarter of a mile to the west of it there is a small exposure of the black limestones, the sandstone being probably concealed in the interval. The dove-gray limestone continues along the cliff in a narrow band for about a mile. There is then an interval of about half a mile from which it is absent, but it again becomes exposed in the vicinity of St. Albans Bay, at the mouth of the ravine leading up to St. Albans, and on the opposite sides of it.

"On the north side it runs along the escarpment of the Potsdam strata for nearly half a mile, approaching to within twenty yards of it. Both rocks dip about S. 80° E., but while the Potsdam beds present a pretty uniform inclination of from 15°–20°, the inclination of the dove-gray limestone varies from 15°–65°. The breadth of the limestone here is about 180 yards, and on the western side of it, which would be the top, there occurs a *Pleurotomaria* very like *P. quebecensis*. The dove-gray limestone here, as farther north, is succeeded by the sandstone, the two being seen in contact and the black limestone follows. On the south side of the ravine there are two exposures of dove-gray limestone, one nearly touching the red strata of the Potsdam group, and the other about a quarter of a mile to the northeast of it, on the left side of the rivulet which flows out from the ravine. The mass near to the Potsdam strata dips in the same direction with them, about S. 70° E., but at a higher angle, the inclination of the latter being 7°–15°, while that of the former is from 20°–45°. The more western exposure of the dove-gray limestone is followed by sandstone, which becomes interstratified with thin beds of black limestone, and is limited by a thick bed of this rock studded with nodules of black chert.

"This is seen where the rivulet flowing from the ravine falls over the escarpment formed by the limestone. In its strike nearly half a mile to the south, a limestone of the same color appears holding *Strophomena alternata*, a *Maclurea* with a *Pleurotomaria*, together with an *Asaphus* like *A. platycephalus*. Opposite to the ravine and in a position which is westward of the northward strike of the Black River limestone, there occur two exposures of the dove-gray limestone constituting two mounds or hillocks, belonging to one mass of rock with a length of about 500 yards and a breadth of 150. . . . It will be seen that between St. Albans Bay and Stanbridge there are two great dislocations connected with the Quebec overlap, the western one running from the outside of the hillocks of St. Albans Bay by Swanton, Highgate Springs and Phillipsburg, to the 21st lot of the sixth range of Stanbridge and the eastern, from the mouth of the ravine at St. Albans Bay, by Smith's limekiln, the Mississquoi valley, southeast of Swanton, the Rock River on the province line, and by the house of Mr. Carruthers to the 129th lot at St. Armand."

Mr. Edson and myself have carefully gone over that part of the region above described, which lies in Vermont, and we cannot fully agree with all of Sir William's conclusions. Our criticisms, however, are not yet ready for publication, as further exploration of the area in question is needed.

Although the account just quoted needs revision, in the light of later work, yet it is a very useful guide to anyone who may wish to explore the territory described. What is called "Potsdam" is really the lower Cambrian, and what is called "Hudson River" is mostly, and probably all of it, Utica. So far as I am aware no rocks have been found in the region which should have been placed in the Hudson River group as formerly understood. Here, as elsewhere in western Vermont, the rocks called in various reports and articles "Hudson River" are, I think, all Utica, and as has been stated, what is properly enough called Utica (characterized by *Triarthrus beckii,* etc.) in many places, grades into the Trenton limestone so completely that it cannot be separated from it. In this region at least the Utica is to be regarded as an upper member of the Trenton, rather than as a distinct formation. (Fourth Report, Vermont State Geologist, p. 207.)

Some years later than the explorations in this part of Vermont carried on by the Canadian Survey, Dr. C. D. Walcott visited the region and in 1886 published in Bulletin 30, U. S. G. S., some of the results of his study with those of investigations in Cambrian rocks elsewhere. Dr. Walcott's statements refer mainly to Georgia, the town next south of St. Albans. Most, if not all, of the rocks in this town are Lower Cambrian, the most famous of which are the shales on the Parker farm. While, I think, all of the species which were first found in these shales have since appeared in other localities, yet the "Parker ledge" is the original and historic locality for *Olenellus thompsoni, Mesonacis vermontana* and other well known Cambrian forms. The Parker ledge outcrop is not a large one, the shale is a hard, siliceous, brown rock, splitting readily into, often very thin, layers. At present it is difficult to find fossils at this place, though if one got out a large mass of the shale he might secure some good specimens, but it would be no easy task to get it out. Moreover, the rock was never very rich in fossils and those that in past years have been obtained there have cost much labor and careful searching.

West and south from the Parker ledge toward the lake shore there is a succession of narrow outcrops of dolomitic, siliceous limestone of a light gray color when fresh, but weathering to a rust brown, sandy material. In the fresh rock there are few or no indications of fossils, but after the oxidation has taken place the casts appear, often very distinctly. Most of the outcrops dip strongly to the east. There are also two fine outcrops of the red and white mottled "Champlain marble," similar to that at Swanton and Malletts Bay. It is

hoped that a more complete investigation of the rocks of Georgia will be possible before the next Report is issued. All of the region has not yet been visited and many of the fossils already collected have not been studied. So far as determined the following species have been collected at or within a mile or so of the Parker ledge:

Olenellus thompsoni, Hall.; Olenoides marcoui, Whitf.; Mesonacis vermontana, Hall.; Bathynotus holopyga, Hall.; Ptychoparia adamsi, Bill.; Ptychoparia vulcanus, Bill.; Ptychoparia arenosa, Bill.; Ptychoparia miser, Bill.; Ptychoparia miser, var, A.; Ptychoparia teucer, Bill.; Protypus senectus, Bill.; Protypus, senectus var. parvulus, Bill.; Protypus hitchcocki, Whitf.; Microdiscus parkeri, Walc.; Kutorgina cingulata, Bill.; Iphidea labradorica swantonensis, Walc.; Orthisina orientalis, Whitf.; Orthisina transversa, Walc.; Nisusia festinata, Bill.; Nisusia festinata transversa, Walc.; Obolus franklinensis, Walc.; Billingsella orientalis, Walc.; Rustella edsoni, Walc.; Scenella varians, Walc.; Stenotheca rugosa, Hall.; Dactyloidites asteroides, Fitch.; Phyllograptus cambrensis, Walc.; Climacograptus emmonsi, Walc.; Planolites virgatus, Hall.; Planolites congregatus, Hall.

To the above list should be added the following: *Olenoides desiderata, Walc.,* Highgate; *Protorthis wingi, Walc.,* Highgate; *Billingsella orientalis, Walc.,* Boulder, St. Albans, which have not been found, as far as I know, in Georgia.

Most of the above are described and figured in Dr. Walcott's FAUNA OF THE LOWER CAMBRIAN OR OLENELLUS ZONE, Tenth Annual Report, U. S. G. S., 18, and many in his earlier paper, Bulletin 30, U. S. G. S.

Of these species *Olenellus thompsoni* appears to be, at least in many localities, the most abundant. Perfect specimens of this trilobite are seldom found or, if found, successfully taken out, but fragments are often so abundant as to occupy a considerable part of the rock. It is evident that very large numbers of this species existed in the upper layers, some of them, of the Lower Cambrian of this region. It is also noticeable that in those layers which contain such abundance of casts of the crusts of *Olenellus,* few or no other fossils appear.

Dr. Walcott's observations are so interesting that a somewhat extended quotation from the account referred to above may well be given here. First, in explaining the adoption of the name Georgia Group, Dr. Walcott says*:

"We use the term Georgia Group to designate this terrane from the town of Georgia in Franklin County, Vermont, where it is developed in its full proportions and where the most interesting fossils have been found. . . . Two reasons may be given for the preference of Georgia: First, the whole of the group is developed in the town of Georgia; second, nowhere but in Georgia, in Vermont, are the characteristic fossils of the group displayed. . . . The geological character of the group is best developed in Georgia, and we are, therefore, compelled to use the name of this town in describing the slates geologically.

"The Georgia slate includes all the following varieties of rock:

"Clay slate.
"Roofing slate.
"Clay slate approximating to micaceous sandstone.
"Various kinds of limestone.
"Brecciated limestone.
"Conglomerate, composed of pebbles of limestone.

"The typical Georgia formation, as developed in the town of Georgia, consists, as seen at the base, of a great thickness of magnesian limestones that pass, in their upper portions, into an arenaceous magnesian limestone that is overlaid by a belt of arenaceo-argillaceous shales and this by a great thickness of a purer argillaceous shale that, high up, carries a brecciated limestone conglomerate and lenticular masses of limestone and sandstone, from the size of a bean to masses 2,000 feet in thickness and several miles in superficial area. A carefully measured section, beginning at the base of the westward facing cliff overlooking the level that reaches to the shore of Lake Champlain, and extending southeastward through Parker's quarry, and a little south of Georgia postoffice, gives the following:

"1. Massive-bedded, bluish-gray dolomitic limestone with many inosculating threads and bunches of a yellowish-drab sandy limestone that weathers in relief	35 feet

*Bulletin 30, U. S. G. S., pp. 14–19.

2. No. 1 passes into a steel-gray dolomitic limestone. . . . At 160 feet from the base the first band of mottled limestone, 'Calico' or 'Winooski' marble is met with. The latter grades into a reddish dolomite, free from mottling, and then into a gray limestone	200 feet
3. Gray dolomitic limestone in massive layers, some of which are mottled reddish and white, but the larger part are gray and yellow	475 "
4. Reddish-pink dolomitic limestone, weathering to a reddish brown and decomposing on the exposed edges to an arenaceous, dark, brownish red rock that shows fragments of fossils....................	100 "
5. Gray arenaceous limestone in rough massive layers, passing into more evenly-bedded, light gray arenaceous limestone........................	190 "
Total limestone........................	1,000 feet
6. Georgia shales, argillaceo-micaceous and arenaceous shales, containing numerous fossils at Parker's ledge and showing deposition contact on No. 5. Strike at Parker's, N. 30° E., dip 8°–12° E..............	200 "
7. East of the Parker quarry the rocks are argillaceous shales, with occasional layers of hard gray limestone, one-half inch to two inches thick, that carry numerous fragments of a linguloid shell.........	3,500 "
8. Light gray quartzite........................	50 "
9. Gray limestone layers with occasional bands of hard argillaceous shale, similar to that beneath the limestone. Many of the beds of limestone appear to have been broken up and re-cemented in situ.......	1,700 "
10. Argillaceous shales, similar to those in the Parker ledge, continue up to the opposite side of the Vermont Central Railroad track. At the base the shale rest conformably against the limestone of No. 9, and above appear to be cut off by a fault.........	3,500 "
Total thickness........................	9,950 ft."

Commenting upon some of the portions of the above layers, Dr. Walcott adds as follows:

"No. 8 of the section, when traced on its strike to the southwest increases in force very rapidly to the thickness of 500 feet or more and also changes from a quartzite to a more or less calcareous sandstone, containing irregular fragments of argillaceous shale. Followed to the northeast, it soon disappears and the limestones rest immediately on the shales.

"Continuing northeast on the limestone (No. 9), it is found to decrease rapidly, and a mile northeast of where it is over 1,500 feet in thickness, the width across the outcrop is not over 150 feet, and soon the shales above it and those below it come together, the limestone having disappeared. Southwest of the line of the section the width of the outcrop narrows, and north of Georgia Plains post-office the entire section is covered by beds of sand.

"No. 9 appears to be a great lenticular mass of limestone, with intercalated beds of argillaceous shale, and more rarely with arenaceous beds imbedded in the argillaceous shales.

"On Mr. Noah Parker's farm a lenticular mass of calcareo-arenaceous rock is exposed on the edge of the first cliff facing the west, where trilobites are found. The mass is small, 25 feet in thickness at the center and about 50 feet in diameter, as seen in the section. Erosion has removed most of the shale from above it, but in a second lenticular mass, just back of it, the shales may be seen resting over and against the upper side of the calcareo-arenaceous rock, and in the shales numerous small masses of a similar rock occur that are not over six inches in diameter.

"On the hill still farther to the northeast, a hard sandrock occurs that appears to be a remnant of a different formation from the shales below, but a close study shows it to be a portion of a lenticular mass left by erosion, and resting conformably on the shales beneath, each dipping 10° east. Several other instances were noticed where erosion had left these masses resting on the shales, and it was not until they were found to pass beneath the shales, to have portions of the shale preserved on their upper surface and to contain the same species of fossils as the shale, that the writer felt sure that they were not fragments of a later formation deposited on the Cambrian beneath.

"It is these masses that Prof. Jules Marcou referred to the Potsdam sandstone. . . . In a letter to the writer dated December 26, 1885, Professor Marcou states that the sandrock at Parker's quarry was referred by error to the red sandrock or Potsdam Sandstone, as his field notes place it in the Georgia series as a lentide.

"A section taken at Highgate Springs, beginning on the line of the same fault as the Georgia section, gave a slightly greater thickness and also more arenaceous matter in the limestone series beneath the Georgia shales.

"The section begins on the east side of the road running from St. Armands, Canada, to Swanton, Vermont, near the house of Eldad Stearns:

"1.	Compact gray siliceous limestone in massive layers	20 feet
2.	Gray calciferous limestone, compact, hard, evenly bedded, breaking into shaly layers in places. Some of the layers decompose on exposure into a reddish sandy rock	180 "
3.	Compact, purplish, pinkish or greenish colored siliceous limestone in massive layers	35 "
4.	Thick layers of buff and pinkish-colored, siliceous limestone, with fragments of *Ptychoparia adamsii*	15 "
5.	Heavy bedded, reddish-purple, fine-grained magnesian limestone, breaking into angular fragments, *Ptychoparia adamsii* in abundance	50 "
6.	Shaly and massive layers of gray and purplish-colored sandstones, containing fragments of *Ptychoparia adamsii,* occurring at various horizons	175 "
7.	Reddish colored arenaceous limestone, with irregularly bedded, massive layers of gray siliceous limestone, and a few more evenly bedded layers carrying fossils. Layers of gray and buff sandstone also occur at intervals	700 "
	Total	1,170 ft."
8.	Georgia shales—Argillaceous shale with interbedded masses of limestone, layers of sandstone and siliceous limestone. In the limestone *Kutorgina cingulata, Orthisina festinata, Olenellus thompsoni, Ptychoparia adamsii,* occur	1,000 feet

9. Heavy layers of siliceous limestone, with layers of sandstone midway, extending about 100 feet.... 850 feet

"The section east of Swanton does not show as great thickness of the limestone beneath the Georgia shales, and a fault line crossing the shales a little obliquely to the strike cuts out a portion of them. On the east side of the fault two or three hundred feet of shales occur, and then a layer of conglomerate limestone, the fragments of limestone varying from the size of a pebble to six feet in diameter."

In Annual Report, Geological Survey of Canada, Vol. VII, J., p. 30, Dr. Ells refers to some of the localities in Franklin County as follows:

"The section of these rocks (Cambro-silurian) south of Farnham, is a very important one and throws much light upon some intricate points of structure in connection with the fossiliferous Quebec group, more particularly as regards the peculiar rocks of Phillipsburg, Bedford and North Stanbridge. This area, beginning at Phillipsburg and extending eastward through St. Armand, and south to Highgate Springs, Swanton and St. Albans, has long been historic. The structure is complicated by faults, some of which are apparently of considerable extent, and in places are overturned. . . . The rocks on the shore of Mississquoi Bay, at Phillipsburg, west of the fault, are blackish gray and black slates with bands and lumps of dolomite, in certain beds of which graptolites are found. The exact horizon of these can scarcely be determined from the fossils obtained, but from their general appearance they would seem to belong to the Trenton (probably lower) series, and they have been so described. They would, therefore, probably represent the extension southward of the beds described as occurring at St. Pie and Abbottsford, which are separated by the great St. Lawrence and Champlain fault from the Sillery rocks of Abbottsford, from the Chazy of Stanbridge and the Calciferous of Phillipsburg, a short distance further south. These beds are also continuous across the boundary into Vermont, and their extension into this state has been described under the head of Trenton-Utica at Highgate Springs. . . . The eastern limit of the Cambrian (Georgia Sandrock) is seen on the road east from St. Armand to Frehligsburg, at the cross-road on lot 126. Beyond this, to St. Armand Center, a series of bluish-gray slates occurs which are calcareous in places and dolomitic-weathering. At times these

contain pebbles like the strata seen east of Granby and on the west side of Sargent's Bay on Memphremagog Lake, as well as at points above referred to. . . .

"The extension of this area into Vermont can be traced on the road leading from Highgate Springs to Highgate Falls. After crossing the ridge of Cambrian, or red sandrock, to the east, the rocks first seen are the bluish gray, dolomitic shales, precisely like those observed on the road from St. Armand to Pigeon Hill and in the vicinity of Mystic. Their contact with the Cambrian is a short distance west of the village of Highgate Falls, and these slates have in Vermont yielded to Mr. Walcott fossils of the Chazy age. Just at the bridge at Highgate Falls, they are apparently cut off by a great overthrust fault, which brings up the Cambrian again upon the Chazy. Going south from this place about half a mile, at Hungerford Brook ledges of blackish shales, calcareous in places, form an anticline at the bridge over the highway.

"These slates have yielded fossils of Cambrian age. A fourth of a mile south of this brook, ledges of limestone and limestone-conglomerate, in places a breccia, occur along the road, associated with great exposures of brown-weathering dolomite which are cut by small veins of quartz. The conglomerate or breccias contain masses of limestone which hold fossils of Upper Cambrian age, such as *Agnostus, Orion,* etc., so that the horizon of the dolomites themselves is apparently the same as that of the associated fossiliferous slates, and they here form the western side of the Chazy syncline. . . .

"A fourth area of Cambrian age forms an important belt further to the east, and extends from the Vermont boundary in a northeast direction, continuously to Kingsey, on the north side of the St. Francis River, where it is prolonged still further in the same direction. . . . Its extension to the southwest is depicted on the map of Vermont by Professor Hitchcock, where it forms the eastern boundary of the Chazy belt already described as extending east of Highgate Falls. It crosses from Vermont into the province of Quebec, near the line between lots 56 and 67, St. Armand. At this place, about a fourth of a mile east of the cross-road, which is one mile south of the Boundary, a considerable hill rises to the left of the road going east, the rock of which is a black slate with large bands of dolomite cut by quartz veins, which constitute in some places nearly half the mass of the dolomitic portion. Occasionally the rock becomes a conglomerate or breccia mixed with the dolomite, and some of the limestone masses contain obscure fossils. The general aspect of these rocks is very similar to that noted as occurring in the Upper Cambrian south of Highgate Falls, Vermont.

"On the road leading southwest from St. Armand Center, which crosses the Boundary on lot 56, the dolomite bands come in about three-eighths of a mile south of the cross-road at that place, with hard, grayish, sandy slates and quartzites. These are thence traceable to the Boundary, where, just to the west of the road, a prominent ridge composed of similar slates, dolomites and quartzite occurs. Fucoidal markings were observed in the slaty beds. A hill of similar rock rises on the road leading to Franklin Center, and on the road going east, just south of the Boundary, the series of grayish, hard, sandy and occasionally dolomitic slates, like those at Frelighsburg, is crossed, and these extend to the village of East Franklin, which is about three and a half miles south of Frelighsburg village, on the road to which place similar slaty rocks are frequently exposed. The bands of dolomite just described may be taken as determining the upper part of the Cambrian for this area, and these can be traced very continuously for a considerable distance to the northeast."

As will be noticed, the Canadian Report just quoted deals wholly with the area along the northern boundary. In addition to what has been given above, it is well to notice that while the red sandrock is developed in considerable force in the town of Highgate, very much of it is destitute of fossils, or at least apparently so. As has been shown, it often happens that these siliceous Cambrian rocks when freshly broken give little or no evidence of any fossils, but after weathering and sometimes decomposition, casts of fossils often in great abundance become visible, and grow more and more distinct as they remain exposed to the weather. An instance of this is seen in a slab of *Dactyloides* which was obtained. When this was first taken out it was not apparent that it contained much of value. After two years or more, during which it had lain fully exposed, the indistinct fossils gradually grew plain until the real and abundant content of the layer was shown. On this account one familiar with the red sandrock and also the shales hesitates to say which layers are fossiliferous and which are not, until he has seen pieces after considerable weathering.

However this may be, the great mass of the red sandrock north and east of the Station at Highgate Springs did not yield any fossils

to a somewhat careful examination. West of the Cambrian, near the shore of the lake, there is Trenton rock. In Swanton, northeast of the Barney quarries, there is shaly rock in which a few *Olenellus*, worm tracks, etc., are found. Farther east a siliceous limestone occurs in small outcrops and in some layers of this *Kutorgina cingulata* and *Iphidea labradorica* are very abundant and finely preserved. *Nisusia festinata* also occurs, but is less common.

And this is true of all the Cambrian rocks that have been examined in the two counties, Franklin and Chittenden, which have been studied especially during the last two years. By far the larger part of the rock is hard, siliceous, and not fossiliferous, at least to any extent. While this barrenness of fossils has prevailed throughout most of the layers of the Cambrian, there are here and there other, usually thin beds, that appear to be almost wholly made up of fossils. Historically the most interesting of the fossils of this region are the trilobites, first found at the Parker ledge in Georgia, though some of them are much more abundant in other places and layers. This ledge first became famous chiefly because of finding there the two large species, *Olenellus thompsoni* and *Mesonacis vermontana*. Specimens of these were first sent by Professor Z. Thompson to Dr. Hall, who described and figured them in the Twelfth Regents Report issued in 1859, "Trilobites of the Shales of the Hudson River Group." The next Report contains a note from Dr. Hall, changing the location of the beds at Georgia from Hudson River to Quebec. In Volume I, Geology of Vermont, 1861, page 175, we find the following opinions expressed in regard to these rocks. After giving a diagram of "a section through St. Albans," with a brief description, the following statement is given:

"Thus we have the whole relation of the Georgia slate represented in this figure. The natural inference from these relations is that the red sandrock is of the age of the Oneida conglomerate or Medina sandstone, and the Georgia slate is still newer, and therefore Middle Silurian. All the members of the Lower Silurian, the Potsdam Sandstone, the various limestones, the Utica and Hudson River slates, lie between the red sandrock and the Laurentian nucleus in New York, and the whole apparently form a successive series of newer and newer rocks, like the corresponding series in New York, from Potsdam sandstone to the carboniferous conglomerate south of the same nucleus. If one wished to establish a palæontological system from the stratigraphical relations of the rocks containing the fossils under consideration, there is hardly a place to which we could refer with such confidence for the true order of strata as to these rocks in St. Albans. Yet it becomes us to speak with caution, because true science forbids too great certainty. Nor have we examined every ledge with compass, clinometer and hammer, as ought to have been done in a thorough survey. The possibility of foldings had never occurred to us until after the close of our examinations in the field." Geology of Vermont, Vol. I, p. 375, 1861. Some discussion of the age of the Georgia rocks follows, in course of which the uncertainty of the writer is made evident.

Then follow letters written by Barrande, Logan and Hall, in which these leaders in the geology of that time express opinions as to the age of the Georgia beds. These letters take up the matter in hand, especially the evidence from the fossils, at considerable length, and all together make an important contribution to Vermont geology. The interested reader is referred to the text of these letters as given in Geology of Vermont, Vol. I, pp. 377–386. It is sufficient for the purposes of this chapter to notice that all the conclusions reached place the rocks much lower than the Vermont geologists had done. A single paragraph may be quoted from Dr. Hall's letter as summing up the whole matter:

"Later discoveries in the limestones associated with the shales at Quebec, leave no longer a doubt, if any could have been entertained before, that the shales of Georgia, Vermont, are in the same relative position, and we must regard the trilobites as belonging to the same fauna with the species enumerated by Sir William Logan, as occurring in the Quebec group. Left to palæontological evidence alone, there could never have been a question of the relations of these trilobites, which would have been at once referred to the primordial types of Barrande."

About the same time, 1861, Mr. E. Billings of the Canadian Geological Survey published a note in American Journal of Science, in which he says, speaking of *Ptychopari adamsii,* which he had not then described and which he found "one mile or a little more east of the Highgate Springs. It is a true primordial type and if we are to be guided at all by palæontological evidence we cannot regard this rock as lying at the top of the Lower Silurian, but at the very base of Barrande's Second Fauna, if not indeed a little lower. It is, therefore, not Medina Sandstone, but a formation somewhere near the horizon of Potsdam. This accords exactly with conclusion drawn from the evidence afforded by the fossils discovered by our survey at Quebec last summer year." Am. Jour. Sci., 3d Ser., Vol. 32, p. 232.

After this there was little disagreement among geologists as to the primordial character of the Georgia formation. Nevertheless the question was not wholly settled for some years after this. Even as late as 1868, Dr. T. S. Hunt, in a paper read at the Chicago meeting of the A. A. A. S., says:

"All the evidence, palæontological and stratigraphical, as yet brought forward, affords no proof of the existence in Vermont of any strata (a small spur of Laurentian excepted) lower than the Potsdam formation."

In Bulletin 30, U. S. Geol. Survey, to which somewhat extended reference has already been made, Dr. Walcott in 1886 placed the Georgia rocks in the Middle Cambrian, for we find throughout the article the fossils of the Georgia beds are referred to this period. As to the relations of these beds with the Potsdam, in which formation most geologists for some years placed these fossils, Dr. Walcott says, page 49:

"In the Georgia section, Vermont, one of the species, *Ptychoparia adamsii,* appears to pass up into the horizon of the 'lentile' of the section, where the fauna is more like that of the Potsdam. Of the other species, *Orthisina orientalis* is much like *O. pepina* of the Potsdam Sandstone of Wisconsin, but the fauna as a whole is so clearly distinct from the typical Potsdam of New York, Wisconsin, Tennessee, Alabama, Texas, Arizona, Nevada and Montana, that even without any section to show their relations with each other, I would not think of correlating them as possible faunas of the same geologic horizon."

Later, in giving a list of fossils limited to different Cambrian horizons, the Georgia species are given as Middle Cambrian, as is also the Georgia Group in a "Classification of North American Cambrian Rocks." In Bulletin 81 of U. S. Geol. Survey, CORRELATION PAPERS-CAMBRIAN, page 113, published in 1891, Dr. Walcott, after saying that during the summer of 1888 he visited Newfoundland and studied a section on Manuels Brook, Conception Bay, that "extends from the Archæan gneiss up to the Olenellus and Paradoxides zones," he goes on to say:

"In this unbroken section it was found that the Olenellus fauna occurred at the base and the Paradoxides fauna above. This necessitated a revision of the classification of the Cambrian. The Lower

Cambrian with the Olenellus fauna is at the base, next the Middle Cambrian with the Paradoxides fauna, and lastly the Upper Cambrian or Potsdam zone, at the summit of which the Dikellocephalus fauna occurs. This correlation places the 'Red Sandrock' series, the Georgia shale and slate series, the 'Granular Quartz' and the 'Upper Taconic' of Emmons beneath the Middle Cambrian or Paradoxides zone of the Atlantic coast."

It is probable that typical Potsdam beds do not occur in large amount in Vermont. As has been seen in what has been said on preceding pages, formerly much of the rock of Franklin County was placed in this age, but more recent and complete examination of rocks and fossils has shown most of the former Potsdam to be Middle or Lower Cambrian, while some of the so-called Potsdam of the writers on Vermont geology of forty years ago is much more recent. Dr. Walcott writes in the Bulletin, 30, referred to already:

"In the review of the references made to the 'Red Sandrock' series of Vermont frequent mention has been made of its correlation with the Potsdam Sandstone as well as of the correlation of the 'Granular Quartz' with the Potsdam Sandstone of the Adirondack area. As now known these two belong to distinct geological horizons, as claimed by Dr. Emmons in 1843. . . . The occurrence of the Upper Cambrian or Potsdam zone as distinct from the Georgia Slate and Red Sandrock, is spoken of in the description of the section crossing the town of Georgia, Vermont, where mention is made of the discovery of a fauna closely related to that of the Upper Cambrian."

As will be noticed in reading the foregoing account, all the Cambrian fossils found in Franklin County have been referred to the lower part of that age or Walcott's Olenellus zone. In the Intraformational Conglomerate mentioned by Mr. Edson in his article on the Geology of St. Albans, Fifth Report, page 143, there are well defined fossils which have puzzled us for some time. These are not at all abundant in the conglomerate, and when found are not easy to get out, but by diligent search Mr. Edson has succeeded in obtaining quite a collection. Dr. Walcott, during his work in the region also secured fossils from this part of the strata. Hitherto no study has been given to these fossils, but a short time ago I took selections of them to Dr. Walcott. On looking over the collections at Washington numerous specimens were found which had come from the same locality. Dr. Walcott gave them a preliminary examination and expected to furnish a list for this report, but has not been able

to do so. He writes, as a result of his brief preliminary investigation:

"The fauna is Middle Cambrian, as indicated by its general facies, and also by the presence of Paradoxides. Thirteen species are noted. One of the interesting occurrences is the presence of Paradoxides in the argillite. If this is the matrix of the conglomerate, it locates the horizon and also proves that the conglomerate is interformational."

While Dr. Walcott does not wish to commit himself as to the specific identification of these fossils, he sends the following list of genera:

Obolus, Lingulella, Hyolithes, Leperditia, Agnostus (two species), *Agraulos, Menocephalus, Ptychoparia* (three species), *Anomocare, Paradoxides.*

It appears very probable that many of the species are undescribed. The important point for the present, however, is the determination of the beds as Middle Cambrian, as no fossils of this period have heretofore been recognized in this state, although it has seemed almost certain that this part of the formation must be represented in our Vermont strata.

In closing this section of the Report, it may be well to explain that the reason for such liberal quotations as are found in the earlier pages is two-fold—that much of that quoted is not readily accessible to the people of this state, for whom the Report is primarily intended, and also because it must be a convenience to any student of Vermont geology to find the more important matter relating to this subject brought together from widely scattered sources.

Geology of the Town of Swanton.

By George E. Edson.

UTICA SHALE.

Commencing at the southern border of the town and passing northward along the shore of Lake Champlain, that is, along the western boundary, high cliff of Utica shale appear. They all dip towards the east. At this point, wherever the shale is seen it rises from the water, the only shore being that which is formed by pebbles of the same material, over which are strewn boulders of gneiss, sandstone and other rocks. Here as elsewhere in the Champlain Valley, the black shale is often crossed in every direction by veins of white calcite.

These conditions continue until the Hotel Champlain is approached and here the construction of a dock has changed the shore line. Northward from this place the shore is low, sandy and pebbly for about a mile, and on the land of O. M. Donaldson it is so low that when the water is unusually high it sets back over the low lands east of Maquam Bay. A small creek empties into the bay, running from the Mississquoi River on the north. By this West Swanton is made an island during some portion of the year.

The shore of the bay is three miles long and nowhere along its extent is any rock seen until near the house of E. S. Tabor, which is on the eastern part of the island, where the shore is covered by small water-worn pebbles derived from underlying shale. Going south by Bloody Point, we find the shore rising until it reaches the highest point on the island. This is near the southern end. South of this Bloody Point the shale forms a high bluff that extends into the lake.

The shore at the foot of this bluff is strewn with large boulders which lie on the upturned shale, since at this place the beds are tilted until almost vertical. Around this point and well up on the western side of the island the shale is still seen standing on edge, reaching to a height of twenty feet.

Just across this part of the lake at Alburg the shale splits in large slabs, and upon their surface may sometimes be seen *Triarthrus beckii* in considerable number, but on this shore no such slabs nor

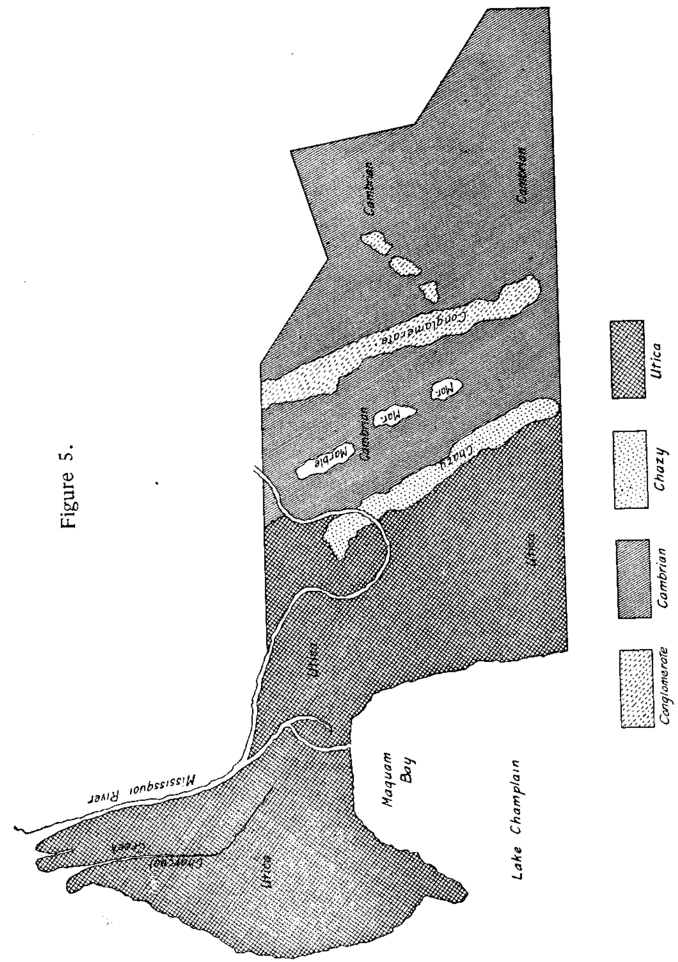


Figure 5.

Geological Map of Swanton.

fossils are to be seen. North of this high bluff, the shore drops abruptly, a break occurs in the rock and the shore is little above water level, and the adjoining land inshore shows marks of yearly inundation. A small bay is seen here, but no rock and the low shore is clay until we reach the northern part, where the shale just rises above the water.

Passing to the land of D. N. Burton, the shore slopes gently upward from the bay and finally forms a bank fifteen feet high, but back from the lake the rock is soon covered. These conditions continue to the north shore of the Point, where the shale breaks off when nearly at its full height, and the shore again becomes low and covered by pebbles and occasional boulders. For more than a mile north from here the shore is low and no rock is seen until near the farm buildings of D. N. Burton, where it again appears in a low bank which, as it proceeds northward, gradually rises and forms a high bluff, the base of which reaches into the lake.

Here the shale dips to the east and only at low water is there any beach to be seen. These conditions continue only a few rods and then the rock goes out of sight and the shore is low and covered by broken and water-worn bits of shale. The shore continues low across the Decker and Niles properties as far as the railroad bridge to Alburg. It is much the same north of the bridge, although occasionally larger stones appear and in places there are growths of rushes and grass. No outcrop of rock appears along the shore for a mile and a half until the land owned by John Moore is reached, where for the last time in West Swanton there is an outcrop.

A short distance north Charcoal Creek and the northern and eastern boundary of Swanton is formed by the Mississquoi River, along the banks of which no shale appears until the falls before the dam in the village of Swanton are reached. Here the shale appears in the bed of the stream and on the western bank.

West of the river and on the land of Homer Brown a small outcrop of shale is seen almost directly west from that seen in the river north and west of the point where the Central Vermont Railroad crosses Charcoal Creek. At the west end of the bridge the shale again appears in West Swanton. Here many ridges of shale appear, especially on the land of Fred W. Tabor, where in an old railway cut shale is exposed for a number of feet. Careful examination of both the shore and interior of Swanton west of the river shows that west of the Cambrian and Chazy all the rock is Utica.

There have no fossils been found except a few *Graptolithes,* which I believe to be *G. pristis,* which were found in the shale from the bed of the river at Swanton.

The determination of the age of the rock underlying West Swanton is based upon its location and lithological structure, the few fossils found and from the dip of the rock across the lake at Alburg. This is Utica beyond doubt, as the characteristic fossils of that rock are there abundant along the eastern shore where the water has worn the rocks, leaving the fossils exposed upon the surface, though none are seen in the freshly broken rock. Along the Swanton shore only the edge of the shale is acted on by the water, so that the conditions are not favorable for exposing fossils. Upon this evidence the rock of West Swanton has been noted on the accompanying map as Utica.

INTRAFORMATIONAL CONGLOMERATE.

"An intraformational conglomerate is one formed within a geological formation of material derived from and deposited within that formation."

This conglomerate shows that some of the sedimentary beds of the ancient ocean had been thrown up, broken in various fragments and falling back into the water, some were worn and others in deeper water retained their angular forms. Subsidence of the sea bottom and changed conditions formed the broken fragments into solidly compacted beds.

The conglomerate is formed of various materials. There is a dark colored, fine grained limestone, a blue or dove-colored limestone, an arenaceous shale in which in some instances are found nodules of limestone and water-worn pieces of bluish slate, which in many specimens are oval, sandstone resembling quartzite, arenaceous limestone, in which the enclosed grains of sand are dark, thus giving the rock a mottled appearance, and light colored sandstone.

The rocks forming this conglomerate vary in size from small fragments to masses weighing many tons.

Wherever the conglomerate shows above the surface, it is smoothly glaciated, especially if recently exposed, and thus its structure is conspicuously brought out.

Wherever it is well exposed, shale is found on both sides of the conglomerate and also interstratified with it.

On the western side, the shale passes under the conglomerate and dips to the east. Along the line of the conglomerate in Swanton, the shale lies at a considerable distance from it and on the eastern side, very little is seen within a mile of the conglomerate.

The same fossils are found in the various limestones and sandstones and in the shale, as well as in the matrix of the conglomerate.

The first outcrop of the conglomerate in Swanton is at the Joseph Warner farm, where the rock appears in the highway, and a short distance north is seen on both sides of the road, but the outcrop is small and low.

The next outcrop of the conglomerate is on the eastern side of the highway on the O. C. Tucker farm.

North of here and on the western side of the highway, the conglomerate shows both limestone and shale. Here there is an outcrop on the land of Fred Collins.

From this point it passes to land owned by O. C. Tucker in an unbroken ridge and extends on northward.

From its first appearance in the town of Georgia, but a few rods south of the line between that town and St. Albans, the general trend of the conglomerate is northwards.

East of the Tucker farm, there is a succession of ridges running easterly, the first of which is on the farm of N. E. Jennison, about half a mile from the highway.

The next outcrop is on the land of Mrs. Beals, where it passes beneath the surface, to appear again on the Warren Robinson farm situated on the East Highgate road in school district No. 6. This locality is about a mile east of the main mass of the conglomerate.

From the land of O. C. Tucker it passes north to that of Joseph Goular, on the west side of the highway, and continues northward in an unbroken ridge to the land of E. Holmes, where it crosses the road and appears on both sides. A short distance west of the Holmes house, the shale that lies west of and under the conglomerate forms a ridge for a short distance, but is here broken by a swamp. In the Adams pasture, situated in St. Albans, this shale lies close to the conglomerate. In the shale the writer has found *Lingulepis acuminata, Con.*

On the Holmes property there is a break and for a quarter of a mile no rock appears. It is next seen on the N. E. Jennison farm in the rear of the buildings on the west side of the highway. Here the conglomerate contains light colored limestone, and to the east shaly stone and the shale is interstratified with the limestone.

The next point northward where rock appears is on the farm of A. K. Honsinger on the west side of the road. From here it passes to the land of the "Old Hoadley" farm. Passing in a ridge through the Hoadley farm it crosses the J. L. Catlin property to that of

Frank Hibbard, where sandstone and shale predominate and but little limestone can be seen.

From here the rock passes to the land of Albert Jennison, and crosses the highway, where a small outcrop of shale appears, and then it goes beneath the surface for half a mile. The next outcrop is on the land of E. A. Grant, where the rock forms a low ridge, dipping to the west. Farther north the conglomerate crosses the "Old Lyon" property onto that of Arthur Rouseau, where there is a small break, and a short distance north it appears on the east side of the road, the shale cropping out on the west of the road. North of the house a large deposit of sandstone crops out, which is glaciated and seamed by white quartz. It again appears on the adjoining farm, the "Old Newton" place, where the conglomerate lies on both sides of the highway, and here passes into the town of Highgate.

NOAH PARKER HORIZON (*Olenellus Zone, Walcott.*)

The type locality of this Lower Chambrian formation is in Georgia, Vermont, where the rocks are shales and sandstones. It is on the farm of Noah Parker, west of the highway passing Chase's corners.

The beds run westward for a mile and a half to the shore of Lake Champlain, where they rest on Utica shale, as a result of overthrow. Here the dip is eastward, as is that of all the Cambrian in northern Vermont. In speaking of the Georgia beds, the terms upper, middle, and lower portions of the beds refer only to that portion of the terrane lying directly back of the Parker house. The first appearance of this horizon is in the town of Swanton, on the land owned by John P. Rich. At this locality the middle and upper beds are well defined. The electric road goes through a cut in the middle portion of the formation. These rocks have furnished portions of *Olenellus thompsoni, Nidusia festinata* and *Ptychoparia adamsii.* At this point is a small valley which runs easterly across the formation and brings the rock into view. The beds are next seen to the north across the valley on top of a hill on the Bullard property, where the middle and upper portions are well defined. Although the arenaceous shale of the middle portion is well represented, as it is somewhat crumpled and split roughly, no fossils except fragments of *Olenellus thompsoni* are to be found. Farther north the rough shale furnishes many heads of *Ptychoparia adamsii* (especially where the rock has been split by the frost and the pieces have been weathered. Under such conditions the casts are yellow through oxidation of contained iron. Fucoids are also abundant in the shale and in some localities the whole rock seems made up of *Planolites virgatus* and, occasionally, *P. congregatus.*

Passing over the Bullard property to the farm of J. P. Kelley (the old Cushman farm), we find the middle and upper beds fully developed. Here the shale splits badly and only when much disintegrated does it furnish fossils. Large quantities of stone have been taken from this place for road making and also slabs used by nearby farmers for walks. Scattered over the ledge are small pieces of highly disintegrated shale, from which there have been obtained fine specimens of *Ptychoparia adamsii, Microdiscus parkeri, Olenoides marcoui, Dactyloides asteroides, Rustella edsoni,* and a single *Agnostus interstrictus.* The first *Dactyloides asteroides* found in Vermont was discovered by the writer in the middle portion of the Noah Parker horizon in Georgia in the year 1898. In 1905 in the same beds I found on the land of J. P. Kelley in Swanton three on one slab, but was able to save only one, the shale being thin and badly disintegrated. The crowning success was left for July, 1907, when I removed from the same locality a slab twenty-six inches long by fifteen wide, on the surface of which thirty-five *Dactyloides* can be plainly seen.

At this locality the blue sandstone that represents the top of this horizon has been split by frost and because of this its richness in trilobites is well shown. One piece, eleven inches by fourteen, shows forty imprints of heads and pygidia of *Olenoides marcoui.* Many hand specimens have been found here that contained four or five of these fossils on its surface. North of the Kelley farm a slight break occurs, and the rock is next seen on the land of C. E. M. Bullard. At this locality the Parker beds lie close to the so-called "Winooski marble," and extend to the east about forty rods, the ground rising gradually until it forms a low ridge.

At the top of this ridge are two lenticular masses of limestone that are particularly rich in fossils. For many years these two masses of limestone were considered to be the only ones of the kind in the state. The outcrop is above the shale, containing *Olenellus thompsoni,* and, so far as I am able to determine by careful research, does not contain that fossil. From the first rocks west where the *Olenellus* has been found, to this limestone outcrop there intervenes about thirty rods of

land, covered with outcrops of shale, which in many instances is covered with impressions of the fucoid *Planolites virgatus,* but not a single fragment of *Olenellus* has ever been found in it.

A short distance north of these two limestone masses I found in 1906 two small outcrops of the same rock, one of which I called the *Iphidea labradorica* outcrop, on account of the extremely large number of perfect fossils of that species which it contains.

This and the other outcrop furnished many fine *Kutorgina cingulata, Nisusia festinata,* and a large number of glabellas of *Ptychoparia adamsii,* and a single specimen of *Hyolithes.*

Passing northward to the land of H. Donolson, the beds of sandstone and a few scattered outcrops of shale end the beds of this horizon in Swanton, for between this point and the Highgate line the surface is covered by sand.

THE WINOOSKI MARBLE.

Volume II of the Vermont Geological Survey, 1861, page 774, gives the following:

"The first quarries opened were in Colchester, near Malletts Bay, by Hon. David Reed of Winooski Falls. He selected the name for the new marble and called it after the beautiful river that flowed near his dwelling."

The composition of this marble as determined by Prof. C. H. Hitchcock is as follows:

Calcium Carbonate	35.31
Magnesia Carbonate	42.23
Silica	10.30
Alumina and Iron	12.25
	100.09

The first appearance of the Winooski marble in Swanton is in a cut of the Vermont Railway, near the limekilns of W. B. Fonda at Swanton Junction, at which place the outcrop barely reaches the surface. From this place to the depot at the Junction the marble remains beneath the surface. It next appears a few rods south of the depot on the east side of the road leading from St. Albans to Swanton, on the land of C. E. M. Bullard. This exposure is only a few rods in extent, but the rock rises above the surface to a height sufficient to permit large blocks to be taken from a test quarry that has been opened at this point. Some years ago excavations were made here in search of silver ore. No lead or silver was found, but specimens of mountain cork were obtained, also hematite and a fine yellow clay.

The clay was the only find of any value and a limited amount of it was dug and sold, but the work was soon abandoned, and the shaft is now filled up. The next outcrop of the marble is located on the west side of the railroad, a short distance north of the station and near the junction of the two tracks.

Here there is a break and the marble is out of sight for a few rods and reappears on the land of Louis Laflam on the west side of the highway. Here it forms a low ridge and extends north to the land of Amos Skeels, where it disappears and is next seen on the land of Mrs. Jane Woods, a mile north. Here the Cambrian sandstone rises above the road in a vertical cliff sixty feet high, at the base of which the marble can be seen. The next outcrop is at the surface on the land of Miss Mary Dorman, and it crosses this to that of Charles Bullard. On the Bullard property the marble lies on top of a high ridge and covers a large area, by far the largest in Swanton, and I believe it to be the largest anywhere. It is here that the Barney Marble Company quarries were located many years ago and since then a large quantity of stone has been removed. To obtain this quarries have been worked into the hill in several places, as stone of different colors has been wanted. Although the demand for the marble has been large there remains a large supply.

This is the last exposure of the "Winooski marble" in Swanton, as it goes beneath the surface just before reaching the Mississquoi River and is covered by sand up to the Highgate line.

But very few fossils have been found in the marble. On the polished surface of the stone occasionally specimens of *Salterella pulchella* have been seen, sometimes in patches containing a large number of individuals. There are also more or less distinct fragments of other, but indefinable fossils. In the red sandrock, of which the marble is a member, fossils are not usually seen until the surface is well weathered. Then some of the layers are seen to be filled with *Ptychoparias,* etc. In the marble proper, besides the *Salterella, Ptychoparia adamsii, Planolites congregatus,* and fragments closely resembling *Nidusia festinata* have been found.

The following fossils have been found in the Cambrian beds in Swanton:

Nidusia festinata, Billings.; Kutorgina cingulata, Bill.; Iphidea labradorica, Bill.; Lingulepis acuminata, Con.; Protorthis wingi, Walcott; Salterella pulchella, Bill.; Hyolithes, sp.; Microdioscus parkeri, Walc.; Olenellus thompsoni, Hall; Olenoides marcoui, Whitf.; Agnostuous, sp.; Ptychoparia adamsii, Bill.; Dactyloides asteroides, Walc.; Rustella edsoni, Walc.; Planolites congregatus, Walc.; P. virgatus, Walc.

CHAZY LIMESTONE.

The Chazy limestone is represented in Swanton by a compact, fine-grained, light blue or, as it is often called, "Dove"-colored stone. This limestone is well known for the production of an excellent quality of lime, which has been manufactured from it for many years, as numerous new and old kilns prove. The analysis of this stone is as follows:

Lime	55.83
Magnesia	Trace
Iron and Alumina	.10
Silica	.40
Carbon dioxide	43.65
	99.98

The only evidence throughout the entire extent of this limestone, other than its stratigraphic position, that it is Chazy, is an occasional weathered *Maclurea magna,* which can be seen on a surface where the water has worn the rock smooth, thus bringing out the fossils, since they being harder than the rock in which they are imbedded, are left in relief.

The first outcrop of this rock in Swanton is just north of the boundary line between Swanton and St. Albans, on land owned by J. P. Rich, where a low outcrop appears, and here formerly there were limekilns, but they were long ago abandoned for better localities farther north in Swanton.

Passing over the Rich land, the next outcrop is on land owned by W. B. Fonda. Here the limestone forms a high ridge, which drops off sharply on the western side. The kilns operated by Mr. Fonda are located here. Although a large amount of material has been removed, the bottom of the mass has not been reached, and many years will pass before the ledge will be exhausted. Just north of the Fonda kilns the outcrop becomes broken, and the next appearance is on the farm of Amos Skeels, where it again goes beneath the surface and reappears in a high ridge on the land of Andrew Beebe. In a few rods it disappears to be seen next on the opposite side of the Mississquoi, on land belonging to the Ferris estate. A short distance north of the appearance of the rock here there is a cut on the Central Vermont, and the formation runs into the river and forms the bank for a short distance.

After crossing the Ferris property, it passes to the land of J. P. Rich, Jr., and here Mr. Rich has located his limekilns, at the extreme end of the Chazy in Swanton. Between this point and Highgate all is covered by sand. The great size of the excavation caused by the removal of the stone, bears witness to the large amount which has been burned in the kilns. As this quarry is, as noticed, at the northern end of the limestone ridge, it can be carried no further in that direction, but there is abundance of stone south of the quarry.

Preliminary Report on the Geology of Chittenden County.

G. H. PERKINS.

INTRODUCTION.

Immediately south of Franklin County lies Chittenden. Like Franklin, this county has Lake Champlain along its entire western border, which has been greatly modified in its outline by wave erosion.

The eastern side of the county is quite unlike the western—as much so as the mountains which extend through it naturally make it. The main portion of the Green Mountain range stretches down from the north and passes through Underhill, Bolton and Huntington. Mansfield and Camel's Hump are both partly in this county, and from them numerous foothills spread out over the adjacent country, making it very broken and rugged. The rocks are as different in the eastern part of the county from those in the west as is the topography. In the west, along the lake, all rocks are stratified, limestones, sandstones and shales, while to the eastward crystalline contain the usual Trenton fossils and in the usual profusion and at Thompson's Point a few Beekmantown fossils have been found, but fossiliferous layers are the exception everywhere along the lake shore in this county.

Igneous rock is found abundantly in numerous dikes and there are some intrusive masses, like the hill south of the railroad station at Charlotte. While outcrops of various rocks are everywhere common, very large areas are completely covered by drift, clays, sands, gravel. These deposits vary from a few inches to nearly a hundred feet in depth and, rarely, they may be even deeper.

The whole area of Chittenden County is 520 square miles.

While the surface of drift covered areas is often sandy or gravelly, there is usually below this a blue or drab clay, much of it a very good brick clay.

As in the reports preceding this, Professor Hitchcock and others have written of the surficial geology of this county, and as in the present volume, the article by Mr. Merwin has somewhat upon the same subject, this will not be discussed here.

The writer desires that it be fully understood at the outset that this article is only preliminary to a fuller treatment of the geology of Chittenden County in future reports. There are many phenomena which have been observed which cannot be properly considered before much more careful investigation. A considerable amount of field work and of study of the results of such work has already been accomplished, but a great deal more is necessary before satisfactory conclusions can be reached. In many respects the geology of this county is puzzling and difficult because of great, and sometimes violent, changes which have taken place since the rocks were first deposited. This makes the record an interesting, but also a very complicated one.

In the work of exploration which, of course, must precede everything else, the writer has been greatly helped by the patient and careful work of Mr. D. B. Griffin, who for several years has acted as field assistant. Mr. Griffin has succeeded in finding fossils in beds where none had been previously found, and has added greatly to our knowledge of the dikes of this region and the distribution of the strata.

Fossils, which are always the main dependence of the geologist, when he can find them, in determining the age of strata, are notably scarce in this county. Of course none are to be looked for in most of the rocks, as they are metamorphic, but even the stratified beds are singularly destitute of signs of life. It is, therefore, with great satisfaction that quite a number of hitherto unknown localities have been found and, in some cases, abundant fossils taken out. The comparatively small area of Ordovician limestones at Cedar Beach contain the usual Trenton fossils and in the usual profusion, and at Thompson's Point a few Beekmantown fossils have been found, but fossiliferous layers are the exception everywhere along the lake shore in this county.

The rocks of Milton, Colchester, Burlington, Shelburne and Charlotte are more or less completely stratified and belong to Cambrian and the Ordovician periods, except the Pleistocene deposits which cover much of the surface. Had the metamorphism of the rocks which has been so prevalent throughout the eastern part of the county occurred in the lake region the shore would have had a very different outline from that which we now find, for this outline is largely determined by the character of the rocks which are present.

Where the rocks have been broken, faulted or were exceptionally soft, they have been eaten into by the waves and more or less deep bays are the result. Glacial ice, too, has in some cases carried away much rock on the shore and bays may be formed in this way. Once started a bay, especially if exposed to strong winds, is continually enlarged by the wearing of waves. Hence the tendency of an irregular shore line is to grow more irregular, unless the headlands are themselves worn away, as is always the case to some extent, but only as they are destroyed at a more rapid rate than the shores of adjacent bays are they likely to be obliterated. Then they are, and the shore line becomes more regular. Originally, then, the shore line of Chittenden County was more regular than now, and its present bays did not exist. The ancient shore line ran from Shelburne Point through Rock Dunder and Juniper to Appletree Point and thence to Colchester Point, and all to the east of this line was dry land. This was the condition at the close of the Ordovician.

But this was in the early geological time and consequently long ago. Before this, very likely, the sandstone of Red Rocks was continuous with that at Rock Point, and before the rock, black shale, that composes the points first mentioned was formed, when these points and the space between them was laid down in the seas of the Utica period, towards the close of the Ordovician, the old Ordovician sea slowly ate its way into the meager land area and cut out a bay which was bounded by Red Rocks, the high cliffs of the north side of Shelburne Bay, and the cliffs of Rock Point. These were probably neither of them as high as later. Certainly Rock Point, as will be shown, was then very different from what it is now, for enormous upheaval and disturbance has taken place there, but there were cliffs in very ancient times, ancient even geologically. In those remote days, and perhaps more recently, Lake Champlain was a river rather than a lake and ran through a narrow channel, which it wore down till it had formed a cañon, and this was probably where the ship channel, nearer the New York than the Vermont shore, is now found. That is to say, the deep channel, in some places 390 feet down to the bottom, is an old river cañon. Very slowly, but constantly, changing through the long geologic ages, the shore line of this county affords a most interesting story to him who will exercise patience and observation enough to decipher it. The whole story is far too long for this place and must be abruptly broken off. The story is a thrilling one to the geologist, and perhaps no part of it more so than that which relates to the great breaking up and throwing up of vast masses of rock to be more fully described later, by reason of which we today find at Malletts Head, Rock Point and elsewhere much newer rock under the older.

THE ROCK FORMATIONS OF CHITTENDEN COUNTY.

Whatever there may be buried below our observation we may not know, but the oldest rock in the county which we can see and study is the red sandrock which is considered to be Lower Cambrian. This rock occupies a rather narrow strip through the extreme western border of the county from the north edge of Milton, which it enters from Franklin County, on through Charlotte into Addison County.

Although the name "Red Sandrock" has been given to this formation, the rock, as has been abundantly shown in writing of Franklin County, is by no means all red nor all sandstone, though much of it is. It is more homogeneous, very much so, in Chittenden County, than in the region north and in Canada. Here it is largely, though not wholly, a red sandstone.

Perhaps the rock at Willard's ledge, now Phelps quarry, which is so largely used for foundations and may be seen in several buildings, is as typical an example of this rock as can be found, or quite as good. The formation extends through western Vermont from Highgate to Bennington. In the quartzites and shales of Colchester, as in Sunderland Hollow, it is not easily recognized. Some of the more characteristic fossils are *Nisusia festinata, Kutorgina cingulata, Iphidea labradorica, Ptychoparia adamsi, P. miser, P. vulcanus, Salterella pulchella,* and especially, *Olenellus thompsoni.* These and other of its fossils place the formation, as Dr. Walcott decides, in the "upper part of the Lower Cambrian."

Not only do we find, as was just noticed, other sorts of rock in this formation, but where it is all sandrock there is much variety. If anyone can see the high cliff, shown in Plate XLVII when the late afternoon sun gives unusual distinctness to the different layers of which it is composed, he cannot fail to admire the beauty which variety of shade in the reds of the stone gives to the picture, and a picture it is, which favorably seen will be remembered. Or, though less finely, the same may be seen in the ledges at Phelps quarry.

Here the eastern wall of the quarry, which is about forty feet high, shows layers varying much in thickness from a few inches to forty feet, and in color from dark red or red brown to almost white.

In the sandrock there are some thick layers, as at Mallets Bay, where the old marble quarries were which tell of deeper water, but for the most part it was a very shallow water formation. In Phelps quarry there is abundant and undoubted proof of this, for there are ripple marks, sun cracks, mud flow surfaces and all sorts of plain indications, or rather unquestionable proofs, that the stone was—must have been—formed in very shallow seas along the shore.

Indeed, we may best think of this ledge as part of that very ancient shore which rose from the almost primeval ocean and as, probably, a low reef came nearly to the surface of the water. As the sea bottom sank, new layers were deposited upon those already laid down and so, in course of many years, the comparatively thin strata accumulated until in all several thousands of feet of rock were formed.

From what has just been said it will be seen that any analysis of the sandrock must be that of a single layer only, for each of the layers which are found in every cliff of this stone will show a somewhat different composition. That is, while the same substances may be found in all, or nearly the same, they are in quite different proportions. Some layers contain a perceptible amount of lime, others little or none, being nearly pure quartz. Some, the dark red, contain more iron, others, the whiter, have little or none. An average specimen would have about the following composition which is of a specimen from Charlotte and is given in the Vermont Report of 1861.

Silica, SiO_2	83.80	per cent
Alumina and iron	8.70	"
Lime, CaO	1.12	"
Magnesia, MgO	.10	"
Potash, K_2O	4.59	"
Soda, Na_2O	.45	"
Loss by ignition	.80	"
	99.06	per cent

The Champlain, or Winooski, marbles which form a member of this group, vary somewhat from the above and show a decrease in silica and increase in lime.

Analysis of Champlain marble:

Silica, SiO_2	19.304	per. cent
Alumina and iron	12.251	"
Lime, $Caco_3$	36.310	"
Calcium carbonate.		
Magnesium carbonate, $MgCO_3$	42.235	"
	100.00	per cent

The varieties of this marble which are now worked by the Barney Marble Company of Swanton have been described in the section on the varieties of Vermont marble in the first part of this volume. Similar varieties and many others, differing more or less from them, but quite as attractive, are found at Malletts Bay and within the Burlington city limits, where it has been quarried. It is unnecessary to repeat here what has already been said concerning the variety, beauty and brilliancy of these red and white marbles. It must be sufficient in passing to simply call attention to them. Evidently in the limited areas in which they were formed, a different set of conditions prevailed from those elsewhere; the water was deeper, the rock, a part of it at least, was broken into angular fragments, some of it softened and the whole mixed in a confused mass which hardened into the marble we today find. The only fossil that has been definitely determined from this marble is *Salterella pulchella,* a little cylindrical object only a fraction of an inch long and sometimes occurring in crowded groups, as in Plate XXXIX, which shows one of the first specimens found. It is, however, only in rare pieces of the marble that any of these are found. There are other objects that I believe to be fossils, but they are so ill defined that they cannot be identified.

The beds of the marble and those of the sandrock appear to be continuous and to grade into each other.

Local disturbances, which sometimes occur, aside, the sandrock everywhere dips to the east, and usually at a low angle, 10°–30° and often much less. Where anticlines and other disturbances appear the dip is of course much greater.

This rock forms the shore of Lake Champlain from some rods north of Malletts Bay, southward about a greater part of the bay, though there is a stretch of drift which forms the eastern shore, making a high bank over which the road to Thompson's Point runs.

PLATE XXXIX

Salterella pulchella, Billings. In Slab of Champlain Marble, Swanton. Reduced slightly.

From Catfish Point on Malletts Bay, Mr. Griffin has made out in passing eastward and at the same time from lower to higher beds, no less than two hundred distinct layers. Some of these are very thin, but some are ten or fifteen feet thick. The total thickness of these beds is about 450 feet. Most of them show all the marks of shallow water formation, and on some various tracks are seen. Plate XL shows a common form of the cliffs of the Cambrian rock on the shores of Malletts Bay. On several of the layers the singular and not very well understood form called *Cruziana*, figured in Tenth Report, U. S. G. S., occurs very distinctly. Most of these layers are red sandstone, but gray or white quartzite occurs occasionally. Some of these quartzite beds are several feet thick and very solid.

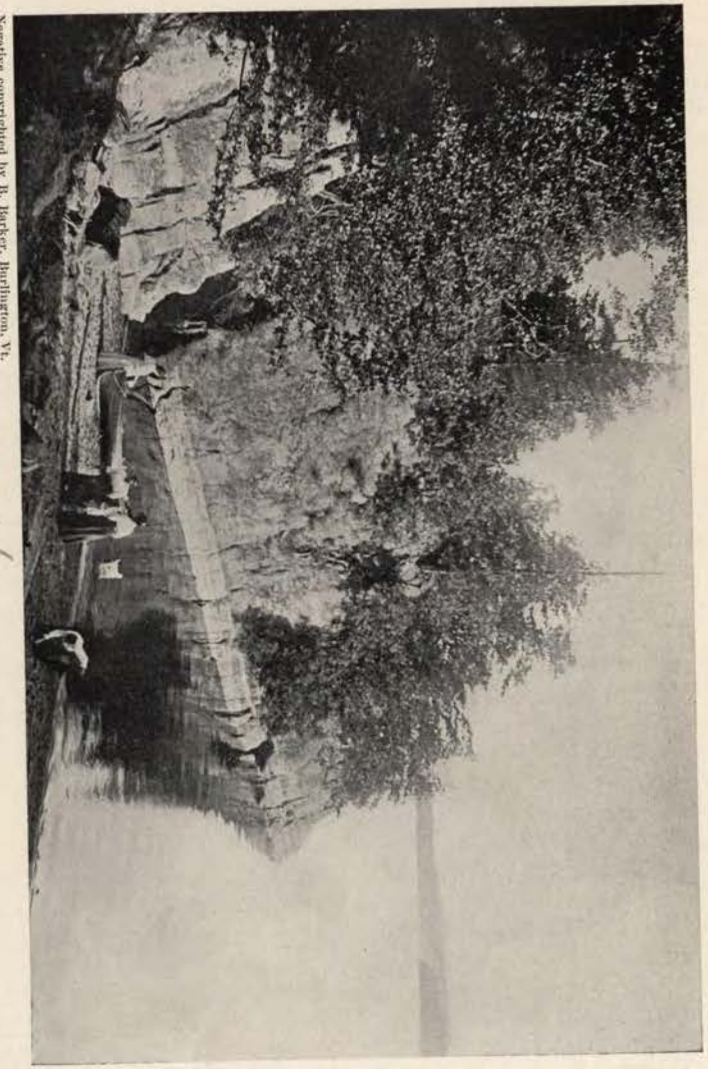
In the lower layers no fossils have been found, except tracks, including *Cruziana*, and it is not till over three hundred feet of rock have been gone over that anything else is found. Then in a fine grained, grayish sandstone *Ptychoparia adamsi* occurs. The following measurements and enumeration of these beds has been made by Mr. Griffin:

"From the shelving rock seen at low water mark on the west front of Catfish Point, Malletts Bay, going east and up, we find:

	Feet.	Inches.
1. Red sandrock with streaks of white quartzite, mostly thin bedded, many layers with ripple marks	13	6
2. Red shales		2
3. Alternate layers of red sandstone and quartzite	2	
4. Red sandrock	2	11
5. Red sandrock	8	
6. White quartzite with *Cruziana* and other tracks	5	2
7. Red sandrock with fine examples of *Cruziana*	3	9
8. White quartzite, massive purple streaks	2	6
9. Red sandrock		12
10. Reddish shales		2
11. Red sandrock	3	6
12. Reddish shales	2	3
13. White quartzite, purple and red banded	2	
14. White and red quartzite, unevenly bedded	6	
15. Reddish sandstone with some lime weathers brown	4	1
16. Red sandrock	2	1

	Feet.	Inches.
17. Gritty sandstone, weathering brown...........	1	4
18. White quartzite...........................	1	1
17. Gritty sandstone weathering brown...........	1	4
20. Red sandrock.............................	1	4
21. Gritty red sandrock.......................	1	1
22. Similar to the above but not like it, weathering brown		11
23. White quartzite...........................	1	9
24. Red slaty rock............................		6
25, 26, 27, 28, 29. Alternating beds of red sandstone and reddish red slaty stone..................	1	18
30. White quartzite...........................	1	10
31. Red sandrock.............................	2	3
32, 33, 34. White quartzite with thin bed of gray shale	7	10
35, 42. Thin beds of alternating red sandrock and shaly siliceous rock.......................	6	11
43. Red sandrock with worm borings, gritty at top	4	2
44, 54. Alternating thin layers of red sandrock and white quartzite...........................	11	4
55. Pinkish quartzite.........................	2	8
56. Red sandrock, thin bedded.................	1	5
57, 58. Red sandrock.........................	8	8
59. Massive white quartzite...................	3	4
60. Red sandrock.............................	1	1
61, 71. Beds mostly red sandrock, often gritty and with ripple marks.........................	34	1
72. Gritty pink quartzite, weathering brownish yellow	2	3
73, 83. Alternating layers of white quartzite and red sandrock.............................	25	6
84. Reddish quartzite.........................		7
85. Red shale................................		1
86. White quartzite...........................		9
87, 88. Yellowish shale and gritty rock...........		7
89, 95. White, pink and gray quartzite, rather heavily bedded	35	9
96. Red sandstone with worm borings............		6
97. Similar to 96, but with fucoid-like markings...		6

PLATE XL.



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Lower Cambrian Sandstone, Malletts Bay.

much the same succession in the different layers. Here again I follow Mr. Griffin's notes, although I have been over all the region with him as guide. A short distance north of Catfish Point there is the best exposure of the typical Cambrian sandrock to be found about the bay, or at least on this side of it. Still farther north, near Perch Point, the sandrock changes, becomes more calcareous and dolomitic and forms a bed of marble which is here about fifteen feet thick. In sandrock just above this *Ptychoparia adamsi*, and, possibly, other species of this genus are found. This is the lowest layer in which we have found these fossils. North of Malletts Creek there is a heavily bedded, light grayish quartzite and above this is another bed of the Champlain marble. Then comes a fine grained, dark quartzite containing *P. adamsi*, etc. North of this is a conglomerate made up of the marble and quartzite, but no fossils have been found in this. There are two small and two larger dikes which cut through these beds here.

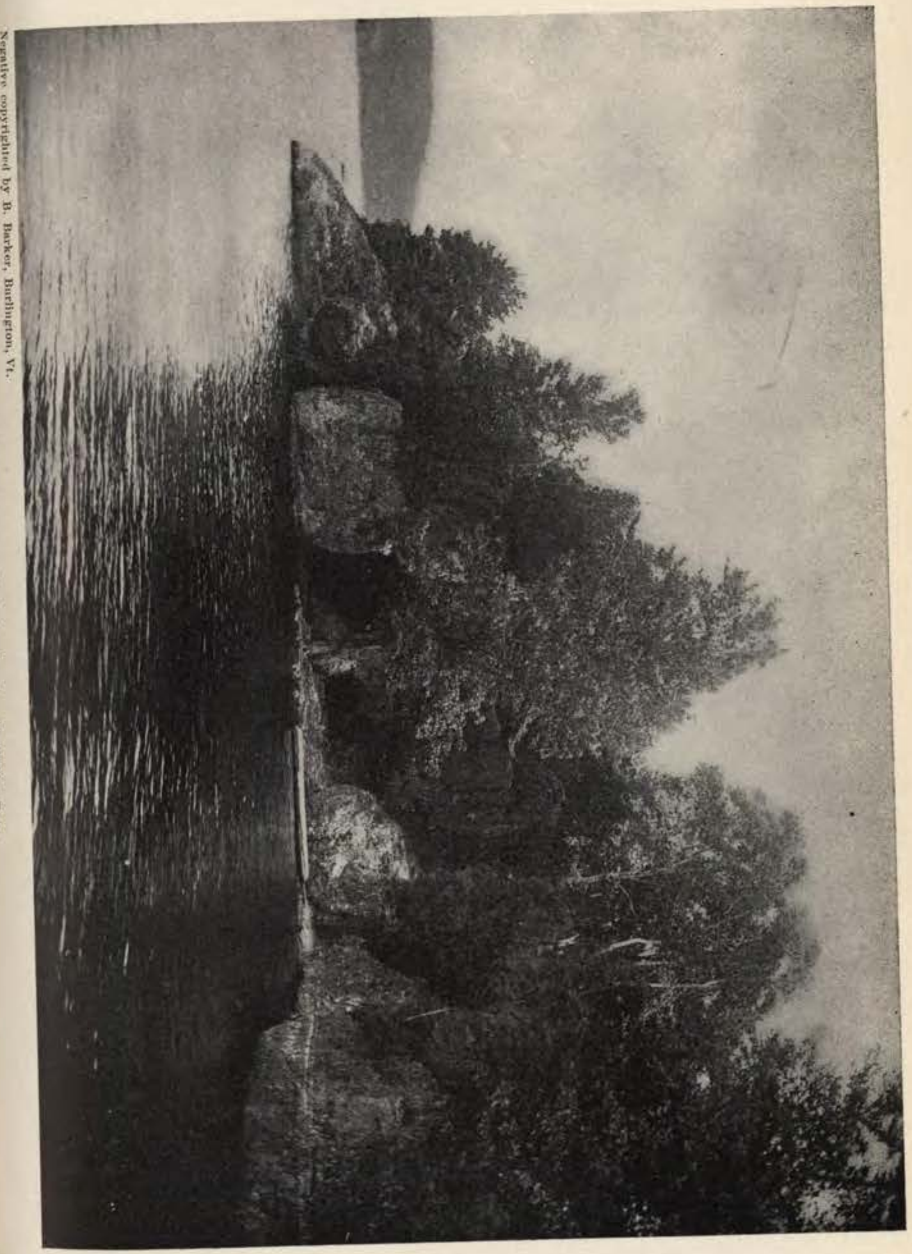
From this point to North Beach there are various beds of quartzite. After passing the sandy stretch of North Beach for a half mile, rock again appears, a siliceous limestone of a grayish color. From North Beach to Marsh's Bay the rock is a gritty sandstone containing a little lime, especially those layers highest above the water.

Bass Rock, which is at the middle of Marsh's Bay, is a good example of this rock and is of a brownish color where weathered. In several places conglomerate is seen.

From Marsh's Bay on the rock is a siliceous limestone with small masses of chert. North of here there is a small sandy beach and then the same rock appears. Below high water there is on the east side of a little bay beyond Marsh's a layer of gray, very fine grained sandstone containing little lime. Where the rock has gone out, or at least is not now present in the clays and sands, Pleistocene shells, *Macoma fusca* and *Saxicava rugosa* mainly are found. Above the fine gray sandstone mentioned, which also occurs on the west side of the little bay, Salterella occurs in a reddish sandstone.

From here around to Eagle Rock the Champlain marble is well exposed, the beds at the rock being 40 feet thick. Just north of this cliff Utica appears. Above the Utica is a smooth breaking limestone, which is identical with that underlying the Champlain marble at the Wakefield quarry. There are four dikes here within a short distance. This limestone was formerly burned for lime.

Near Gale's brickyard at Clay Point and for a short distance be-



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Marble Island. Red Sandrock, Malletts Bay.

PLATE XLI.

yond, the rock is Utica. The upper half of Clay Point and most of the beach near is clay, beyond which to the Lamoille River the shore is sandy. The thrust fault, which will be more fully described in speaking of Rock Point, is not only seen in the cliffs just mentioned, where the Cambrian limestones and sandrock rest on the Utica, but also is well seen at Malletts Head, where the same conditions are found. At the Head the shale is very greatly twisted and broken. The shale also appears south of Malletts Head at the S. E. part of Thayer's Bay. Here a tongue of much tilted shale extends out into the lake and forms a little point. Along the southern part of Thayer's Bay the shale again appears for several rods as the lower part of the shore, being topped by Champlain clays.

Returning to Malletts Head and going back east, we come to a gravel beach in the upper part of which are numerous *Macomas, Saxicavas,* and *Myas.* Just east of this beach and about thirty feet above it on the cliff of Champlain marble which rises from the shore, there is a very large pothole. From the beginning of this cliff on eastward, the shore rock is the Champlain marble and out in the bay is the pretty Marble Island, Plate XLI, which is wholly of this stone.

Wherever the rock is wanting and sandy or clayey beach appears there are Pleistocene shells, usually *Macoma* or *Saxicava,* but sometimes *Mya.* For some rods along the shore the rock is marble, broken by open beaches. Cave Island and a small nameless island are in the bay east of Marble Island and show the same rock. In this *Salterella* is found. On around the bay by the McVicar camp over a longer stretch of Pleistocene clays and sands, we come to other beds of the marble. There are near here two rock masses in the bay which are composed of the siliceous limestone that underlies the marble. The very lowest beds on the eastern part of Cave Island are also this limestone. This is a smooth fracturing rock, dark gray, somewhat striped with lighter bands, and where it appears it is overlaid by the dolomitic marble.

No fossils have been found thus far in this underlying limestone, but it resembles that north of St. Albans near the Barney marble quarries in Swanton, in some parts of which, as has been noticed in our study of Franklin County, numerous *Kutorgina cingulata, Iphidea labradorica, Nususia festinata,* were found.

From Pickerel Point, where the rock ceases, for over a mile to

Thompson's Point there is, near the bay, no rock, but a high bank of Champlain sands and clay.

North of Malletts Bay, inland, between the bay and the Lamoille River, there are heavy beds of gray quartzite and a yellowish, compact, thin bedded sandstone. This is especially interesting because some of the layers are very full of fragments and nearly entire glabellas of *Olenellus thompsoni*. Some fine slabs of this two feet long and half as wide and not more than half or three quarters of an inch thick can be obtained here, the entire surface of which is covered with very distinct casts of *Olenellus*. No perfect specimens and, indeed, few pygidia, have been found here. Plate XLII shows a small part of these slabs. No other species has yet been found in these layers. The locality appears to be quite restricted in area, but is very noticeable because of the scarcity of any fossils in by far the larger part of the rocks of this county.

West of these *Olenellus* layers and below them, are layers of the ordinary red sandrock, exactly like those at Highgate, which contain in places an abundance of *Ptychoparia adamsi*. Thus far no other species has been found in these beds. There seems to be an entire separation of *Olenellus* and *Ptychoparia* in these layers. Neither occurs with the other. Farther south and west, back of the farmhouse of Mr. Severance, there is a little quarry in siliceous shale in which *Hyolithes communis* and what appears to be *Lingula gonvillensis*, Walc. occur.

Coming back to the shore of the Lake at Gale's brickyard, we find, as has been seen, that near there, Utica occurs in not very large exposures. From here north across the mouth of the Lamoille River to and for a considerable distance beyond Sandbar Bridge, only sand and occasionally clay is found along the shore. On the north side of the Lamoille, not far from the lower bridge, is the first exposure of rock. This is a pinkish, or whitish, limestone, which occurs above the Champlain marble. About the middle of Fox Hill, near the first farmhouse as one goes east, there is a fine grained, red, siliceous limestone, grading into sandstone, in which a few fossils occur, among them *Salterella*. On the east side of Fox Hill, fossils, *Hyolithes*, etc., occur.

In that part of Colchester called Champlain there is, in the western border near the lake, a ridge of Champlain marble which extends north from near Clay Point to the Lamoille, being thickest in the south. From this towards the east there is more lime in the rock,

PLATE XLII.

Gray Sandstone filled with *Olenellus thompsoni*, Colchester.

and then quartzite, especially a mile or more east of the ledge of the "marble," and when the little Burns-Martin Valley is reached the rock is quartzite. There are ripple marks and worm borings precisely like those found in similar beds on the shore of Malletts Bay. The white quartzite, however, has here a much greater thickness.

A little further north and east, near Mr. Johnson's, there is a bed of the dolomite or Champlain marble some fifteen or twenty feet thick. Above this, which itself lies on top of a heavy bed of white quartzite, are grayish layers containing *Olenellus*.

Southward from Malletts Bay the sandrock appears here and there away from the lake, but does not come to the shore for five or six miles, following the main road. Following the shore it is more than twice as much. At Rock Point there is a massive and very interesting bed, which has long been known to geologists as an excellent example of a thrust fault or overthrust.

On the side of Rock Point, which forms the northern boundary of Burlington Bay, only a massive cliff of the sandrock is seen, over a hundred feet high, as shown in Plate XLIII, but on the opposite side, after passing around the Point, a wholly different condition is found. Here next the water, instead of sandrock, black shale is seen and above it is a thick mass of light yellowish, when weathered, calcareous, dolomitic sandstone. It is called "a limestone" by Billings and a "saccharoidal sandstone" by Kemp. It is a very good variety of the Champlain marble, some account of which has been already given. It is calcareous enough to effervesce with acid, but still quite siliceous. Half a mile or so east near North Avenue it has been somewhat quarried and a considerable amount taken away and sawed into slabs. As shown in Plate XLIV, the underlying shale is fifteen feet or more in thickness and the "marble" perhaps three times as thick. The relative thickness of the two sorts of rock varies greatly from point to point of the mass.

As the plate shows, the shale is cut out somewhat from under the stone above, and the flat underside of the sandstone is smoothed and polished by the slipping over the rock below very noticeably. The shale, too, shows all the customary evidences of moving, crushing, upturning, folding, etc.

The shale is only seen here at the part of the cliff shown in the plate, but the sandstone extends for perhaps a mile northeast, ending near the Winooski River in Ethan Allen Park. The stone continues calcareous to some degree for some distance, that is, nearly as far as

North Avenue, but beyond there it grows more distinctly a sandrock. It is seen in greatest elevation at what is now called Indian Rock, on which the tower in Ethan Allen Park is built. This rock is very nearly two hundred feet above the lake.

From the highest point of the park, and it is the highest eminence anywhere in the region for several miles in every direction, the great mass of sandrock slopes rapidly toward the east and ere long disappears. For a few miles to the east no rock is found, but after crossing the Interval it is seen in numerous places in Colchester, either as red or gray sandrock. North none is found until near Malletts Bay, at the Wakefield ledge, where marble, some of which is in the Albany State House, was quarried for a year or more.

Towards the city of Burlington, aside from the mass exposed at Rock Point, there are several smaller outcrops on the east face of the high bank along which North Avenue runs, but after passing the Institute road a little distance no more appears in the western part of Burlington until near "Oak Ledge."

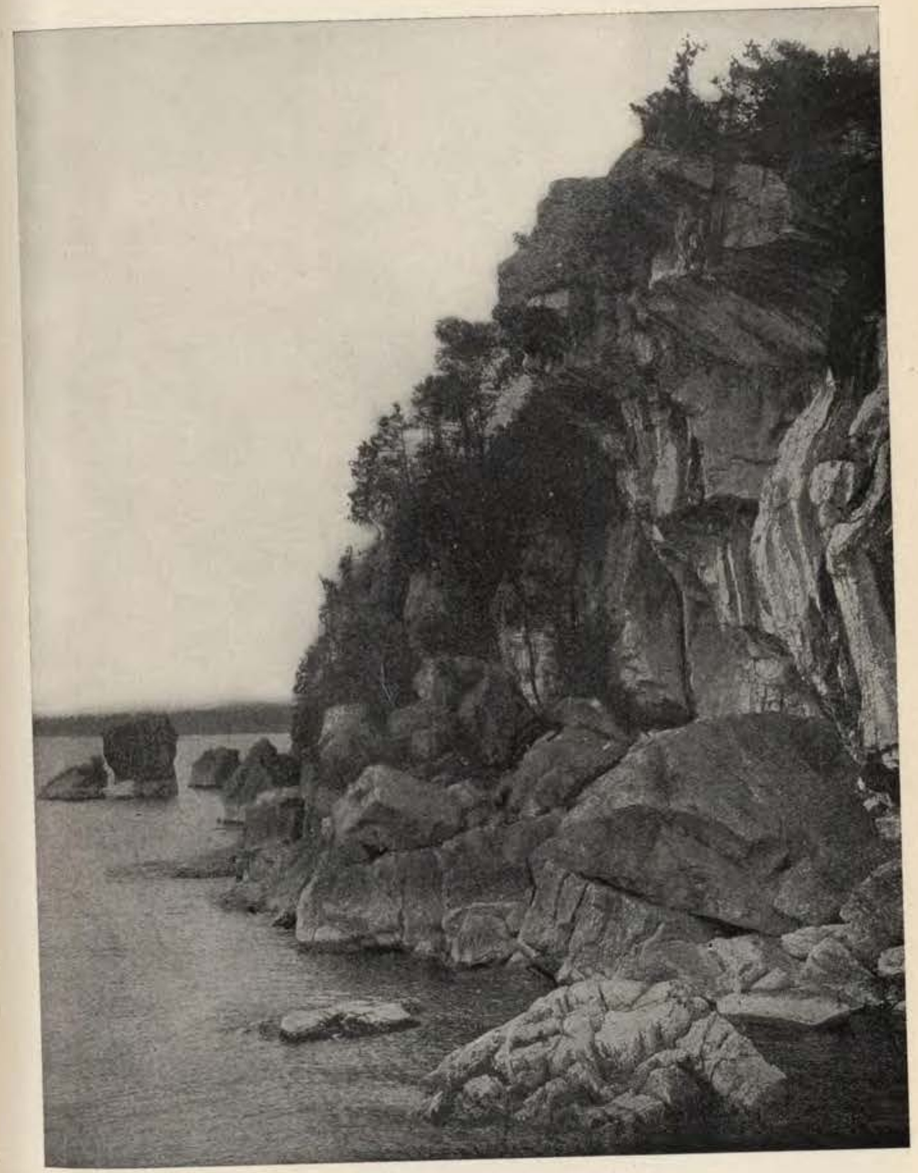
Although, as has been noticed previously, the "overthrust" by which the old Cambrian beds have been shoved over the newer Utica shale, is plainly seen at several points about Malletts Bay, it is nowhere shown as finely as at Rock Point, at the place shown in Plate XLIV. At this point the rock rises according to the U. S. Topographical Survey nearly a hundred feet above the water of the lake. As the plates well show, the rock everywhere rises almost vertically from the water, but it does not reach its greatest height at the outer part, but a short distance inland.

These overthrusts are the result of the disturbance caused by what Logan many years ago recognized as "The Great Fault," whereby for many miles the rocks were broken and those on the east were first lifted hundreds of feet, probably, above those on the other side of the break and then shoved to the west over the newer layers. Whatever of newer layers were raised with the rest have long since been washed and weathered away so that now, as we see in the plate, Cambrian sandrock rests directly upon Utica shale.

South the same disturbance is found, though in somewhat different form, at Snake Mountain. The fault continues far beyond Vermont, crossing into eastern New York, but I do not know that there is seen overthrusting beyond Snake Mountain in Addison.

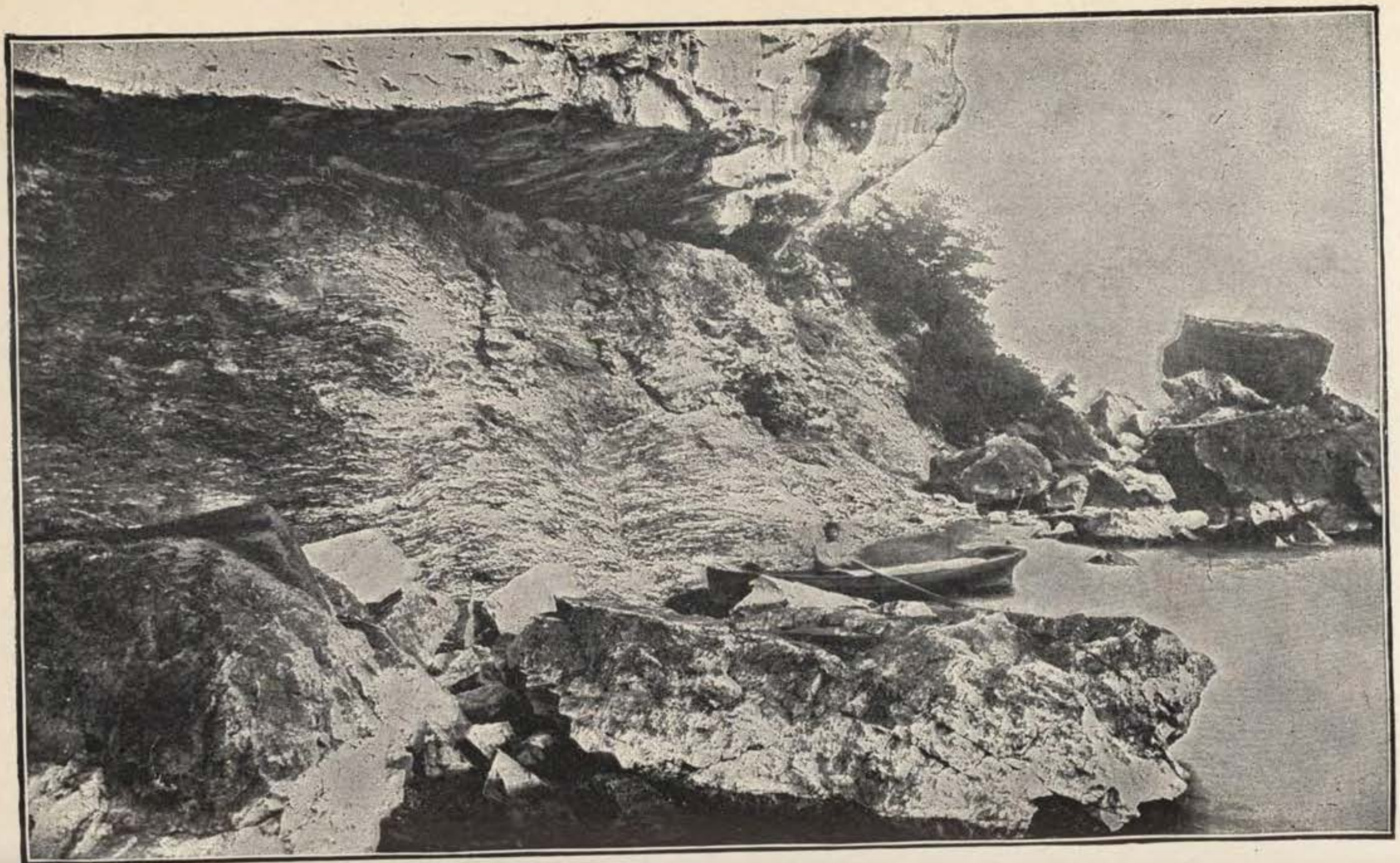
From Rock Point the shore is low and sandy until near Oak Ledge, a distance of over three miles. Here the sandrock again

PLATE XLIII.



Red Sandrock, Rock Point, South Side.

PLATE XLIV.



Cambrian Sandstone overthrust on Utica Shale, Rock Point, Burlington. From Bulletin 107, U. S. G. S.

comes to the surface in low, somewhat inclined outcrop. There is a small mass at or near Lakeside Park; but a few rods south it appears more strongly, and with only a few breaks where there are little bays and sandy shore, it is continuous on for nearly two miles. A short distance west of Queen City Park it disappears in a high bank of drift. Between three and four miles farther on around Shelburne Bay there is the only other outcrop of the sandrock on the shore of the Lake. And here there is only a small exposure about on a level with the surface.

Thus for a total distance of about thirty miles along the western border of the county the sandrock crops out at intervals.

As will be noticed later, all the rock on the shore of the Lake on the south side of Shelburne Bay and on south along the Lake is Ordovician. Although not only not visible at the surface, but deeply covered by drift, the sandrock appears to be continuous between Rock Point and Red Rocks. Most of the artesian wells drilled in the west part of the city sooner or later strike this rock, though not all. At different wells the rock was reached at depths varying from eighty to over two hundred feet. One of the wells at the Gas Works goes down a hundred and sixty-four feet and does not reach rock, but a second not far away meets the rock at a hundred and seventy feet. It is evident, therefore, that all of the lower, or western, part of Burlington is built on drift or sea beach formations and underlaid by the sandrock.

While none of the Cambrian rock comes as far west as the Lake shore, south of Red Rocks, it appears in thick beds only a few miles inland, as on the road from Burlington to Shelburne Farms, and on through the county. Going east from Red Rocks, where the beds dip to the east at varying slope, 5°–20°, we find a small outcrop at Potash Brook where there are a few feet exposed. Then on to the ledge in Phelps quarry, where there is exposed by long quarrying several acres of floor and a wall over forty feet high and in some places more. In the highest part of the quarry wall, taking all parts, there are eighty-six feet exposed. Beyond here there are smaller outcrops for a mile or so. The total thickness is not less than five hundred feet. In most places, after going back a mile or so from the lake, there is no great depth of soil over the rock. In Phelps quarry the evidences of shallow water in which this rock was formed have been already mentioned in speaking of the formation in general. Everywhere this evidence of deposition in quite shallow water is very plain. There are, however, some parts of the beds that indicate somewhat deeper water, but by far the greater portion of the beds were undoubtedly formed in shallow seas along shores. For many years diligent search for fossils has been made at this ledge, but without satisfactory result.

In its character this rock is apparently precisely like that north of Malletts Bay, as also the beds in Highgate, in which *Ptychoparia,* etc., occur, but no trace of trilobite, or brachiopod has even been found in all the many layers at Red Rocks and east of there. Of course, fossils may be found at any time; there seems to be no reason why they should not be. There are what appear to be casts of algæ in great abundance in some of the layers. Dr. Walcott appears to doubt the indications of algæ in Lower Cambrian beds, but it is quite difficult to understand these very abundant fossils if they are not to be regarded as parts of algæ.

On the north of the city near the lower falls at Winooski, the red sandstone appears jutting into the river in a low point. This is seen in the foreground of Plate XLV. All the rest of the rock seen in the picture is a light gray, compact sandstone, dipping towards the northeast at a low angle. On the south side of the river, the right lower corner as one looks at the plate, the light sandstone rises in nearly vertical cliffs from the water to a height of nearly sixty feet, though the upper twenty feet are less vertical, as there is some sloping towards the highway, or "Lower Road" to Winooski. On the opposite side of the river, as seen, the rocks are heavily bedded. The mill and buildings in the background stand on other layers of the same rock.

No red sandrock is found east of that shown in the foreground of the picture, but the gray, all of which seems to be Cambrian, though as it has thus far proved wholly destitute of fossils, its exact location cannot be positively stated, continues for some distance east. A few rods east of the falls seen in the plate there are others not as high, and here are other outcroppings of the gray sandrock. Also on the south side of the river, just below the north side of Green Mount Cemetery, there are several outcroppings, the largest of which has been quarried and used for macadamizing the streets. This rock in some layers contains a little lime and in others grades into a clear quartzite. Two dikes, about two feet and a half wide each, cut through the layers in the quarry. The same gray sandrock crops out in a number of places in Winooski village, and is apparently

PLATE XLV.

Red Sandrock.

Lower Falls, Winooski River.

Gray Sandrock.

everywhere near the surface. Below the surface there are thick beds of sandrock, as borings show. At the woolen mill some years ago a well was sunk four hundred and ninety-five feet. Nearly the whole distance the drills went through the red sandrock, in which they stopped, a few feet of soil only being found at the surface. Not far east of the railroad station at Winooski, the gray sandstone appears in some thickness, about twenty feet, and there is a cut through which the track passes. East of this there are two small cuts, only a few feet of rock showing.

As the road approaches the Gorge, it runs over very thick beds of the sandrock, and not far from where the first of the twin bridges crosses it comes to an end and is succeeded by limestone. Further study of this region is necessary before the limits of the sandrock and the limestone can be made out. The west bank of the river at the first, or west, bridge is undoubtedly the Cambrian sandrock, and probably both sides are, though the east side of the river shows some difference in the rock, and the rock of the island on which the power plant is placed is in some places clear sandrock and in others it seems to have a little lime, though nowhere is the lime abundant.

As we pass to the east bridge the stone on both sides of the river is clearly limestone, and on the east bank of this part of the stream only clearly characterized limestone is to be found. If, as seems to be true, the sandstone is Cambrian and the limestone Beekmantown, there should somewhere be a well marked line of division between them, and this line must be between the twin bridges. Plate XLVI shows the eastern part of the bend at the Gorge. Here the rock on the east, or right, side of the picture is all clearly limestone, but at the foot of the bank in the back of the picture there are several little outcrops of sandrock, just at the water's edge when very low and covered at high water. The rock on the left of the picture about which the stream has cut its way is also probably limestone of the same age as the other, but as to this I am not sure. It is not the same stone, but does not differ very greatly. At the highest point the limestone cliffs rise above the river nearly a hundred feet, though none so high appear in the plate. Plate XLVIII shows the limestone cliffs on the east side of the river near the east bridge.

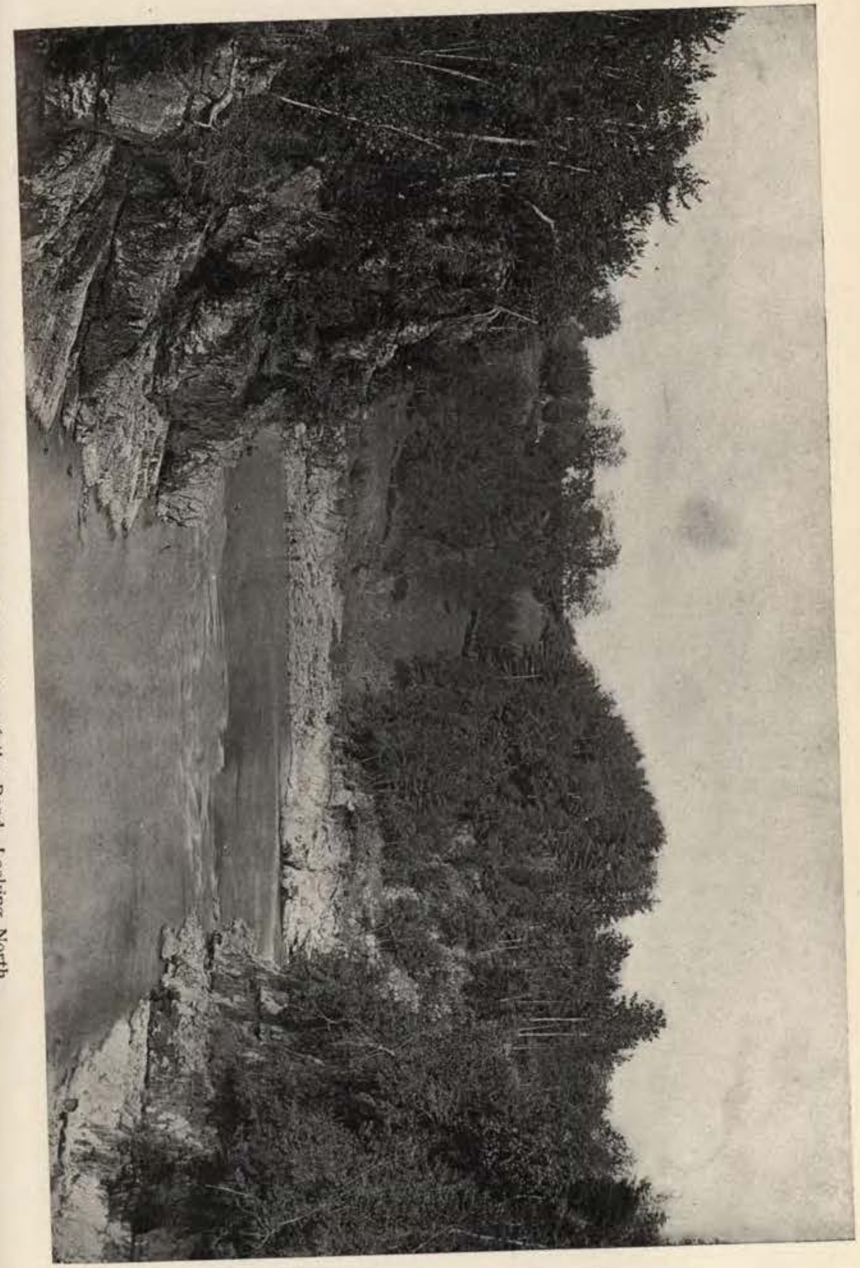
Returning to the shore of the Lake, the sandrock is found, as has just been noticed, south of what is known as "The Addition" in Burlington. Here at first the beds are low and dip northeast at low angles. Yet there has evidently been much disturbance in some parts of the rock, for it is greatly shattered, so that it would be impossible to take out a block of much size. Many of these broken layers are cracked in every direction into small angular fragments of only a few inches in any dimension. But these broken beds are only occasional. Others, and these are much more numerous, are not broken, though all are more or less tilted. As everywhere in this formation, there is great diversity in the character of the layers. Some are shaly, others thick bedded. Most is a dark and rather bright red. Near the high cliff at the entrance of Shelburne Bay there are layers of dark, gray shale, closely resembling the *Olenellus* shale at the Parker quarry in Georgia. Beginning as a low outcrop the rock increases in thickness, forming a ledge along which there is for the most part little or no shore and continuing around the high bluff, the south side of which is shown in Plate XLVII to form the northern side of Shelburne Bay for some distance, and a few rods before reaching Queen City Park it goes under a high bank of drift. The whole extent of this exposure is over a mile, probably a mile and a half.

As has been noticed, the red sandrock extends through the state in a north and south direction, but its width is nowhere more than a few, usually very few, miles. In this county it is succeeded on the east by what, at least for the present, we consider as the Beekmantown. It is certain, as will be shown, that some of the siliceous limestone which is found east of the Cambrian is Beekmantown and it appears very probable that all of it is of that age.

The varied and numerous layers of red sandrock in Colchester have been fully described. Nowhere else do these show so finely, and in Burlington and South Burlington, while in places, as we have seen, this rock is finely shown in cliffs on the shore of the Lake for short spaces, as at Rock Point and Red Rocks, yet as a whole the formation is better shown in Colchester. And when it comes to fossils there is nowhere in the county where anything at all like some of the fossiliferous layers of Colchester can be found.

At the highest point shown in Plate XLVII, for which I am indebted to Professor Kemp, the rocks rise nearly a hundred feet above the water, and farther inland a short distance they are sixty feet higher, as at what is called "The Eastern Outlook" at Red Rocks Park. There is a dike not far below the first outcrop and farther down three more of considerable size, as is shown in that part of this paper which takes up the dikes of the county.

PLATE XLVI.



Gorge of the Winooski River. East portion of the Bend, Looking North.

For several miles beyond Queen City Park the shore has no rock in place, but at the south end of Shelburne Bay there is a small outcrop about level with the surface, and this is the last seen of the sandrock on the shore of the Lake, all the rock south of this point being Ordovician, all members of which are found at one or another locality.

The non-fossiliferous character of most of the Cambrian rocks in this region has been mentioned and also the fact that, in some cases, the absence of fossils is apparent only since when the rock is weathered fossils hitherto unseen come into view. In some few layers of the sandrock fossils can be plainly seen at all times, as in Plate XLII, but more often they are scarcely visible or not at all until long weathering has oxidized the material and brought them into distinctness. This has been shown in the case of rocks of this age in Franklin County. Specimens from the Colchester beds have been studied by Dr. Walcott and he has very kindly identified the following species, all of which were found within a few miles from Burlington, but in the town of Colchester:

Ptychoparia adamsi, Billings; Ptychoparia arenosa, Bill.; Ptychoparia miser, Bill.; Ptychoparia miser, var.; Ptychoparia teucer, Bill.; Ptychoparia vulcanus, Bill.; Olenellus thompsoni, Hall; Protypus desiderata, Walcott; Microdiscus speciosus; Nisusia festinata, Bill.; Scenella varians, Walc.; Stenotheca rugosa, Hall; Lingula gonvillensis, Walc.; Salterella pulchella, Bill.; Hyolithes communis; Cruziana, sp.; Planolites; Scolithus.

Several other forms occur, but they are not sufficiently plain for identification. There are also several kinds of tracks, worm borings, etc. In addition are what have been already mentioned as possible algæ.

Dr. Walcott, 19th Report, U. S. G. S., gives twenty-eight species from the Cambrian rocks of western Vermont. Several species should be added to these and, naturally, additions are continually likely to be discovered. These are grouped as follows: Sponge 1, Celenterates 2, Brachiopods 6, Lamellibranchs 1, Pteropods 2, Crustacea 2, Trilobites 11. In some of the layers markings which appear to be identical with those shown in Fig. 2, Plate LIX, 10th Report, U. S. G. S., have been found. According to Nathorst, these "Eophyton" markings or casts have been made by medusæ as they moved over the sea bottom. The figures referred to are of Swedish me to consider that they are all of animal origin, and that many of the so-called species were formed by one species of animal. Also that specific differences in the animals making them would not generally be shown in the casts of the burrows of trails." l. c. 604.

In the two counties, Franklin and Chittenden, which are especially discussed in this volume, we have the best display of Cambrian strata which is found in the state and on this account it may be well to add to what has been said as to the rocks of this formation in these counties some general remarks on the Cambrian of the state as a whole.

Some repetition of what has already been given on foregoing pages is unavoidable, but no more of this than seems necessary to continuity of statement will appear.

The beds of rock that have been satisfactorily determined as Cambrian in Vermont form a narrow strip which extends through the western part of the state between the Green Mountains and Lake Champlain. From the Canadian border south for about fifty miles, the area occupied by them, they are never far from the shore of Lake Champlain and here and there they form cliffs or headlands. The formation extends northeasterly from the Vermont border to the Gulf of St. Lawrence and southward through Massachusetts and New York down to the middle of Alabama.

How large a part of the metamorphic rocks of the Green Mountains are altered Cambrian strata cannot be told, at any rate not at present, but it is most probable that these beds have contributed to the mountain masses. Most of the Cambrian of Vermont is to be placed in the lower division, or the "Olenellus Zone" of Walcott.

It is also very probable that there are Cambrian rocks east of the Green Mountains and between them and the Connecticut River, but much yet remains to be determined as to the age of the rocks of eastern Vermont and I do not feel like speaking positively as to them.

Three or four miles south of Burlington the Lake shore is occupied by Utica shale and nowhere south of this point do Cambrian rocks come to the shore or near it, all the rocks along the Lake being Ordovician south of that point. Ordovician rocks, mostly Utica, also form the northern shore from St. Albans twenty miles north.

As is well known there was for a long time discussion, and often quite earnest, as to the age of these rocks. As long ago as 1847, C. B. Adams placed certain portions of the Cambrian in the Medina sandstone and both Professor Adams and others, including the geologists of the old Vermont survey which published its final report in 1861, held to this opinion. The first to move these beds towards their proper place was Dr. Emmons, who soon after Adams had assigned them to the Medina, asserted that they should be placed lower, either in the Calciferous or Potsdam. Adams' views, however, appear to have prevailed at that time and for many years afterwards.

Mr. Billings in 1862 from a study of the fossils concluded that Emmons was correct in his location of these beds, and that they belonged in the Potsdam. This view was generally accepted by geologists until Dr. Walcott took up the study of the Cambrian and showed at first that the Vermont red sandrock should be placed in the middle portion of that age and finally, after a study of the Newfoundland beds, that they belonged in the Lower Cambrian and here undoubtedly they will remain.

There is no doubt that the older geologists were puzzled and misled because in several localities, as Snake Mountain, Rock Point, Malletts Head and elsewhere, they found the sandrock beds resting conformably on a black shale which they identified as Utica or Hudson River. For this reason they supposed, naturally, that the Vermont beds must be newer than the Utica. I am not quite sure, but I think that it was Sir William Logan who first recognized a great fault that ran from Canada on for many miles southerly through Vermont, and that the location of what by that time were regarded as Potsdam strata above the Utica was a result of this fault and subsequent overthrust.

Even Mr. Billings did not recognize the true state of the beds, and it is interesting to find him writing in the American Journal of Science in 1862: "At the promontory called Sharpshins (Rock Point) on the lake shore near Burlington, the cliff seems to consist of black slate at the base, overlaid by what appears to be a whitish magnesian limestone. This place has been several times described, but what struck me as particularly worthy of notice is that the under side of the limestone where it is in contact with the slate is smoothed, presenting very much the appearance of slickensides. I infer from this that, either there is a fault here, or that the limestone has moved on the surface of the slate." Mr. Billings' limestone is really a white calcareous sandstone.

Of course since this overthrust has been recognized, there has been no difficulty in assigning the superincumbent beds to their proper place.

In the Cambrian of western Vermont we find, as has been shown in some detail on previous pages, a variety of beds. There are numerous and thick beds of limestone, 1,000 feet or more, which seem to lie at the bottom of the series. Above these there are, according to Walcott, 8,000 or 9,000 feet of shales, sandstones, slates, quartzite conglomerates, breccia. Not only are these diverse in composition, but also in color. Red is the prevailing tint of the sandstones, varying from light pink to dark red brown, the limestones always very siliceous, are drab or gray, the shales are gray or brown or light, the quartzites are white or gray or bluish, the slates are purple, green and variegated and are the well known roofing slates sold all over the country.

As a rule the beds throughout the whole are not greatly disturbed. This is true even along the line of the great fault and overthrusts. Of course there are anticlinals, tiltings and foldings here and there, but altogether these form an inconsiderable part of the whole.

By far the greater number of the beds dip at a low angle, perhaps 20° on the average, though often much less, in an easterly direction, i. e., towards the Green Mountains. Some of the beds are thick and of deep water origin, but most appear to have been formed in shallow areas. Ripple marks, worm tracks, sun cracks, etc., are common everywhere in the shales and sandstone. Very few of the beds are prolific in fossils; most of them seem to be quite destitute of anything of the sort. Even where many fossils have, during past years, been found, they are never abundant. There are, however, thin layers in the shales, as we have seen, some of them of very recent discovery, in which fossils are very abundant. Generally only a few species are found in any one locality and, indeed, altogether the number found in the state is not large. I suppose not more than fifty.

As we have seen, some of the beds afford quite a variety of trilobites, brachiopods, etc., while others are very full of one species and scarcely any others.

Historically, the most interesting part of our Vermont Cambrian is what we call the Parker ledge. It is here that the first fossils of note were found and many have since been obtained, though not at any time very numerous. *Olenellus thompsoni*, *Mesonacis vermontana*, as well as smaller trilobites down to the tiny *Microdiscus parkeri* have made the locality somewhat famous. Most of the species collected here have been described and figured by Dr. Walcott in Bulletin 30, U. S. G. S., and more fully in Annual Report, U. S. G. S., 10th. Certainly no one has done so much to disentangle confusion and to make known the geology of the Cambrian of Vermont as has Dr. Walcott. The same, or similar, shales bearing the same species occur both north and south of the Parker ledge, and undoubtedly new localities will yet be found.

In places, interstratified with the shales, but generally occupying localities where it forms the whole or chief part of the rock, are the various beds of quartzite and sandstone which make up what has for many years been known as the red sandrock. This is much more widely distributed through the state than any other member of the Cambrian. It occurs in several places between St. Albans Bay and Shelburne Bay, just south of Burlington, along the shore of Lake Champlain. It also forms some of the boldest headlands and a series of hills, some of them over 1,000 feet high, which are conspicuous as they stand between the Green Mountain range and the Lake, not as a ridge, but as isolated masses.

In a former part of this chapter it has been shown how the members of the Sandrock series vary from white quartzite, which is purely siliceous, through more or less calcareous and sometimes magnesian beds of all shades of red and varying hardness. The red and white mottled marbles well known to the trade as Winooski or latterly Champlain marbles, belong in this series. Though not usually very thick, and always very siliceous, the sandstone, in a few localities, becomes thick bedded and much more calcareous and in many portions brecciated. It is this that furnishes the "marble." The red sandrock is found both north and south of Burlington and underlies the city. Burlington Bay is included between Rock Point and Red Rocks, which are headlands of this rock. There is a large quarry in the south part of the town from which for fifty years building stone has been taken. During all these years no fossils have been found in this quarry except what appears to be algæ, the casts of which are very numerous.

In the same sort of rock, and probably not far from the same horizon, some of the layers when weathered exhibit trilobites, *Ptychoparia,* in abundance and also a few brachiopods. In almost all the localities in which fossils have been found, trilobites are more numerous than other fossils, but in the limestone, as might be expected, brachiopods are most numerous.

Cambrian fossils have been found in many localities in the slate

PLATE XLVIII.

Beekmantown Limestone. East side of Gorge of Winooski River, near east R. R. Bridge.

belt of Rutland County. Commercially this is the most important part of the Vermont Cambrian, for the annual sales of roofing slates, purple, green and variegated, as well as a large amount which is sawed into slabs for structural or other work, amount to nearly a million and a half dollars.

THE BEEKMANTOWN LIMESTONE.

(Calciferous.)

As has been noticed, there is a gray limestone found throughout the county to the east of the red sandrock. This varies considerably in constitution and color. In the typical localities, as at High Bridge, Plate XLIX, it is a bluish gray, smooth fracturing limestone; elsewhere it contains more silica and is rough and broken and in places it is so highly siliceous that it is almost a sandstone. It is what is called "Eolian Limestone" in the 1861 Report, and is so indicated on the geological map, but there is no very satisfactory account of its range through the state, nor of its character. While it is found in the western line of towns from Milton through Colchester, Burlington, Shelburne into the northern part of Charlotte and extends eastward into Essex, Williston and Hinesburg, it is not largely developed in these towns and does not appear, so far as yet ascertained, in the towns in the immediate Green Mountain region.

I have not been able to find the actual contact between this limestone and the red sandrock, but it is certainly not more than a few miles east of the Lake in any case and often quite near. It occurs on the shore to no great extent, but at Thompson's Point in Charlotte it forms a fairly bold cliff, Plate L, though the Vermont Report of 1861 does not recognize its appearance in the immediate vicinity of the Lake. Near Burlington it is finely exhibited on the east side of the Gorge, Plates XLVI and XLVIII, and near High Bridge, Plate XLIX.

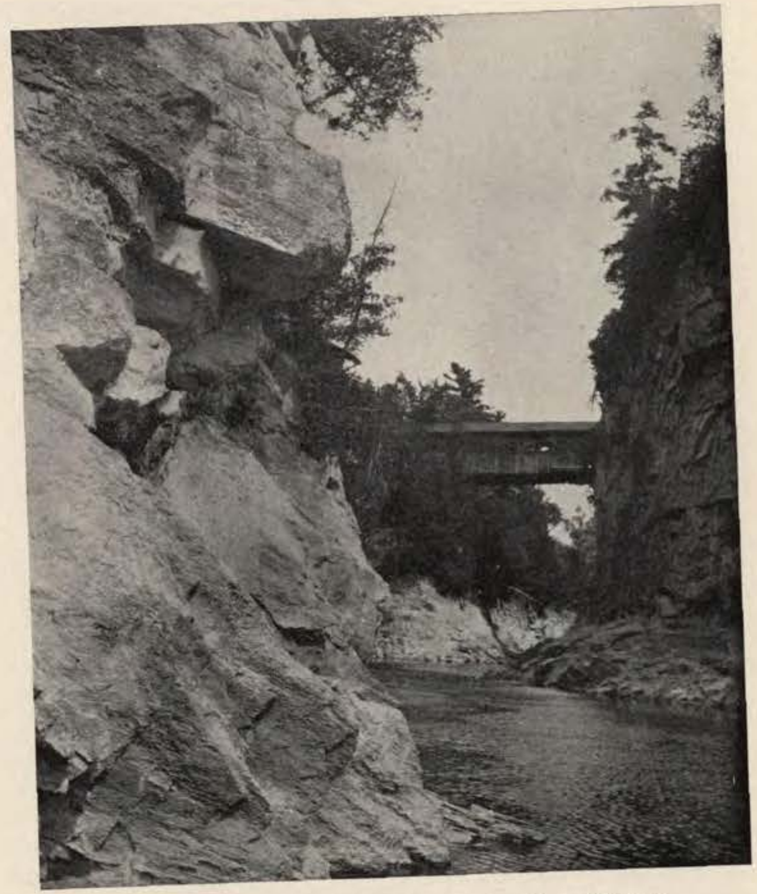
As intimated in the discussion of the red sandrock formation, there is a very noticeable change in the appearance and, to a less extent, character of the rocks below the lower falls at Winooski, Plate XLV.

For some time I thought that the gray sandrock, which there succeeds and overlies the red sandrock, was of a different age, and so long as no fossils whatever are found it must be uncertain whether this is true or whether they are simply different members of the same Cambrian formation. In this Report I have chosen the latter alternative. The gray rocks appear to be entirely conformable with the red, and exploration of various outcrops farther east, while thus far yielding no fossils, do show all the characteristics of Cambrian strata. More than this, in one place I have found, too indistinctly to furnish ground for anything like a positive statement, markings that seemed to be parts of *Olenellus*. Of course, if these could be certainly identified, the question would be settled. Still, this rock has everywhere a Cambrian appearance.

Going east from Winooski the siliceous beds are found, as we have seen, until we reach the eastern of the Twin Bridges at the Gorge. Here the stone on the eastern side, as may be seen in Plate XLVI is unquestionably limestone and contains very little silica. The whole of the cliffs seen on the right side of the picture are of this limestone, but as we pass about the bend under the bank in the background of the picture the rock that crops out is the same gray sandrock that is seen a mile back at the falls. The eastern railroad bridge crosses the Gorge not far from the bottom of the picture and below the bridge on the west side the limestone also appears. The cliffs on the west side north of the bridge, those on the left of the picture are unlike those opposite and also unlike those farther west towards the falls. They seem to be in a way intermediate between the Cambrian sandrock and the Ordovician limestone, but no such transition is to be looked for or possible, hence the whole relation of these rocks to each other is thus far a puzzle for which no solution is offered. From the east side of the Winooski on through Colchester and into Essex the limestone continues. At Essex Junction its eastern limit appears to be at Hubbels Falls, a half a mile or so east of the covered wagon bridge across the river on the road from Essex Junction to Williston. Here, not far below the old dam, the limestone comes squarely against a compact bluish black slate. There has evidently been a great deal of disturbance here. The limestone is greatly broken and displaced and the slate is pitched up at a high angle, and on the south side of the river it is in some places quite vertical.

There is also a considerable dike cutting through the limestone and slate. Veins of white quartz in the slate and calcite in the limestone add to the evidence of disturbance. The limestone is for the most part highly siliceous, though it effervesces freely. The beds of the limestone here are thick and the cliffs and masses in the bed of the river are very rough. The cliffs shown in Plate XLIX are so

PLATE XLIX.



High Bridge, Gorge in Limestone cut by Winooski River.

pure that for many years a large quantity has been burned for lime. The kilns of late years have been located only a few rods from the north or left end of the covered bridge, but in former years there was an extensive quarry still farther north, and several kilns near it. The limestone is very thick here at the river, and just back the cliff rises a hundred feet, while back of the old quarry towards the Fanny Allen Hospital there are about a hundred feet more. Between the lime kilns and Essex Junction the surface is deeply covered with the sand, etc., of what has been considered an ancient delta, but beneath this it is probable that the limestone occurs everywhere. This is indicated by borings for wells at Fort Ethan Allen. There are here a number of deep wells, all of which have been sunk through several hundred feet of sand, gravel and clay before the limestone was reached. The river has cut four channels or gorges through the limestone near High Bridge. There are the three well-known cuts, that shown in Plate XLIX, the two spanned by the railroad bridges, and an older than these which is about an eighth of a mile south of the covered wagon bridge, where, when the land was at a different level from that at present, the river cut its way through the cliffs and the old channel can be seen very plainly after it has once been found. It is at the west of the road going south from the bridge. There is a depression crossing the road, and by following this through a meadow the cliffs about the old river bed can be readily found and the water-worn and gouged surfaces tell the story beyond a doubt. I do not think that examples of the effects of erosion are often seen that surpass those shown in these cuttings made by the Winooski at different times through the limestone, for we have here at and near High Bridge not only the gorge or cut shown in Plate XLIX, but the other three of which I can present no illustration. First the river flowed south of this bridge shown in the plate and in a more direct course through the abandoned channel, avoiding wholly the cut seen in the plate. Then, probably in the latter part of glacial times, the land levels changed and the river left its old channel and was directed into its present course and began cutting its way down into and through the limestone ledges which were in its way. Deflected first one way and then another, it finally settled into the very sinuous channel in which it now runs. Leaving Hubbels Falls at Essex Junction, it runs, with numerous small bends and curves, in a general southwesterly direction for rather more than a mile, then it turns almost due north, a little west of north, for less than a half mile, then it makes a sharp turn to the west for another half mile, then northerly, a very little east of north, for a mile and a half, which brings it to the turn of the Great Oxbow, well seen from the road not far beyond the military post. At this point is the well-known and remarkably sharp bend, where in a short distance the course changes from a north to a south one and for over a mile the two parts of the river bed are separated by only a narrow strip of meadow, and where nearest they are only about thirty rods apart. Here, where most closely brought together, the sides of this long, narrow loop separate and the river turns, after a more than semi-circular bend, to the west, in which direction, though with somewhat of curving and bending, it goes on to the bridge at the lime kilns, flowing first west, then north for a short distance, then west until it nearly reaches the old bridge. It begins to turn south just before it reaches the bridge and soon is flowing almost directly south. In about a third of a mile it makes a very regular U turn to the north and flows in this direction for another third of a mile, coming out at the place seen in Plate XLVI, having, as seen in the picture, just passed under the east railroad bridge. Here it begins to meet harder rock, that on the left as we have noticed being much more siliceous than the limestone on the right, as one looks at the view. It also met something, probably a mass of compact clay, in the bank in front, for it could not cut its way through it, but instead turned right about and with what seems a great waste of labor, cut another gorge through the sandrock at the first or west railroad bridge. As seen in Plate XLVI, the river is flowing directly north. It turns about the mass of rock seen at the left and flows on the opposite side directly south, separating as it turns and leaving the great mass of sandrock between the dam and the power station as an island. After a course in general a little west of south for over half a mile, the stream turns more directly west and so continues through Winooski until near the railroad bridge at the foot of Prospect street, when it turns north and flows on in a northwesterly direction past Ethan Allen Park. It might be tedious to the reader if the river were followed further. All this is, I am aware, quite familiar to most of those who live in the vicinity, but I am sure that they will allow me to call attention to the really remarkable manner in which the Winooski has cut its way through earth and rock, clay, limestone and sandstone in such a curiously irregular fashion. And yet there is much regularity in its irregular way. Why has it worked out this

course? For it has worked its way through the various obstacles noted. Why has the river at the Oxbow in those great meadows in Essex gone, as nearly as I have been able to measure it, a distance of over two miles and a half, when if it had gone across lots in a straight course it could have reached the same point in a little more than a fourth of a mile? Why did it cut its way through the limestone at the second railroad bridge (as one goes from Winooski) only, so far as one can see, to turn right about and cut its way back again through the still thicker and harder sandrock at the first bridge? Why, oh why?

There might be given a somewhat elaborate explanation of all this, but it must be sufficient to notice that powerful as running water is, and none of us is likely to overestimate this power, it is only as it is *running* that it exerts much force; and as a stream, blindly of course, goes on its way from source to mouth, it meets all sorts of hindrances. By these the current is turned, now this way and now that, and its force can be efficient only in the direction which it takes, so that in going from one place to another it can possibly take only the course in which the current is directed, and this may not be at all the shortest nor the easiest, and it usually is not. Not seldom after a stream has taken the longest way around it finds the shorter way and follows it. Therefore it is very probable that, starting when in flood, the Winooski will cut through the narrow bit of land at the base of the Oxbow loop and establish its course there. It must be always remembered that the changes we have supposed to have taken place were not effected in a short time. There is no evidence of rapid movement, but rather that the elevation and subsidence of the land and the changes in the course of the river were gradually and therefore slowly brought about. The cliffs now fifty to a hundred feet high rose slowly from a much less height. The river at first flowing over the surface of the rock, slowly wore its way down. Slowly the rocks were elevated, slowly the water cut down, until after, it may be, many thousands of years the conditions about the gorge and High Bridge came to be such as we now find; and changes are still slowly going on. But the Winooski River has led us away from the rock formation we began to discuss; let us return to it.

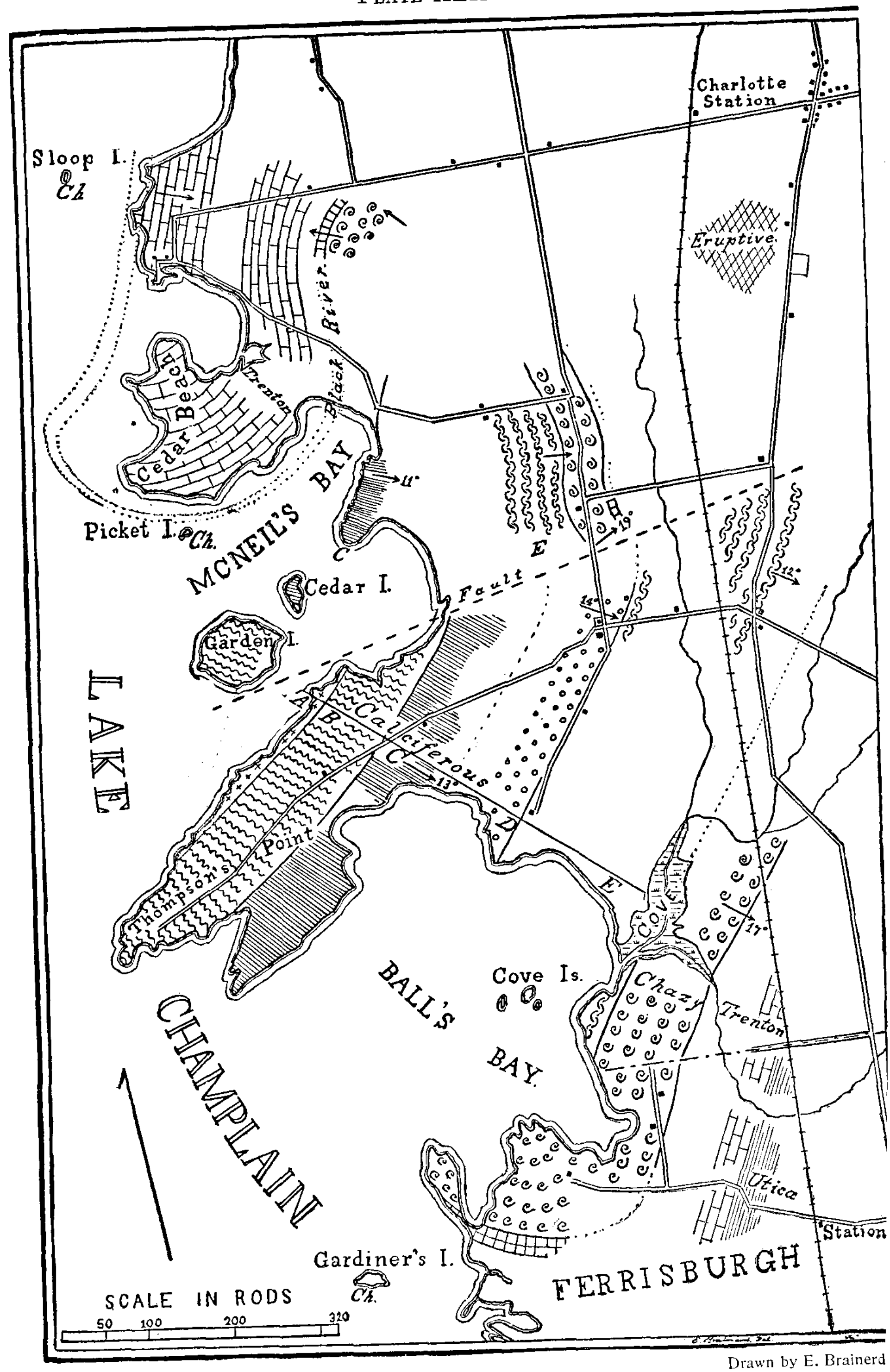
It may be well to give at once the reason for considering the limestone of the gorge and its neighborhood as Beekmantown. The entire absence of fossils from nearly all the exposures makes its exact correlation very difficult, but at one place, not a long distance north of the old quarry at the lime kilns, Mr. Griffin has found fossils. These are few, but fortunately very distinct and readily recognized. In somewhat waterworn and weathered masses of the limestone excellent specimens of *Rhaphistoma canadense* Bill. have been taken out, as well as *Cryptozoon wingi* Seely, and other indeterminable fossils. These are both Beekmantown species and are, I think, sufficient to definitely fix the age of these limestones. It is much to be desired that further exploration of both this limestone and the gray sandstones may bring to light other fossils.

So far as I have discovered, this limestone does not appear on the lake shore north of McNeil's Bay in Charlotte. Here it forms the southeast shore of the bay, Cedar and Garden islands, and the whole of Thompson's Point. These rocks were first carefully studied by Messrs. Brainerd and Seely. In Bulletin of the American Museum of Natural History, New York, Vol. III, pp. 1–23, there is an account of the CALCIFEROUS (Beekmantown) FORMATION IN THE CHAMPLAIN VALLEY, from which it has been found very helpful to quote in previous reports. This article is accompanied by maps and sections which are most useful to anyone interested in the geology of the region discussed.

As to the Thompson's Point locality, these authors say: "Twenty-eight miles north of old Fort Ticonderoga, at Thompson's Point, is another remarkable display of nearly all the members of the Lower Silurian (Ordovician). It is another monocline dipping southeast from 12°–20° and extending from the north shore of Thompson's Point two and a half miles across the strike, to the line of the Rutland Railroad. The lowest strata in sight are thirty or forty feet of iron gray magnesian limestone, containing chert in beds one or two feet thick, supposed to be the top of Division A. Then appear the light gray massive dolomites of Division B, forming high cliffs sloping to the south, a favorite resort for summer cottagers.

"The sandstones of Division C are largely abraded here, the deep bay which bifurcates the point taking its place. They are to be seen, however, at the head of the bay. The magnesian limestones of Division C occupy the remainder of the point, the small bay at the south end indicating the position of the upper sandstone beds of this division. Large masses of black chert are displayed on the shore and on the ledges just south of the road. North of the road these ledges continue on to the head of the bay east of Cedar Island, and in the western escarpments are again to be seen the fine grained sand-

PLATE XLIXa.



Drawn by E. Brainerd

Geological Map of the Western part of Charlotte.

stones of the base of the division. The next hundred and fifty feet of rock is concealed by the soil, but is supposed to be the Ophileta limestones and dolomites at the base of Division D. After this interval the banded sandstones and the blue limestones of this division appear with a thickness of 200 feet, in ledges extending a mile northeast to the schoolhouse. The fossils found here are:

"*Murchisonia obelisca,* Whitf.
Maclurea acuminata, Bill.
Maclurea affinis, Bill.
Euomphalus, or *Oristoma,* sp.
Triplesia lateralis, Whitf.
Holopea cassina, Whitf.
Orthoceras bilineatum, Hall.
Orthoceras brainerdi, Whitf.
Gomphoceros minimum, Whitf.
Lituites eatoni, Whitf.
Lituites interastriata, Whitf.
Asaphus canalis, Con.
Bathyurus, sp., like *quadratus,* Bill.

"The strata of Division E are imperfectly exposed and somewhat crumpled. They crop out over a tract of about thirty acres a mile northeast of the lake, just east of the railroad, dipping 12° to the northeast, and seemingly undisturbed. A thickness of a hundred and forty feet is exposed on three small islands in Ball's Bay, called the Cove Islands, where *Primitia gregaria* and *P. cristata* were collected. Along the north side of Thompson's Point between it and Garden Island appears to be a fault running east-northeast. The drab and buff limestones of Division E are, perhaps, better exposed here than on the south side of the fault, and display a great thickness. Cedar Island consists of the base of Division C, and is one of the few localities where fossils have been found in this division. We collected here an undetermined gasteropod resembling *Ophileta.* Garden Island is composed largely of massive gray limestone of Division B." (l. c., pp. 14–16.)

The limestones at Thompson's Point are shown in Plates L and LI. The map, Plate XLIXa, gives a much better idea of the distribution of the Beekmantown beds than any verbal description can and to this the reader is referred. The map is taken from the Bulletin by Brainerd and Seely, to which attention has been called above.

THE CHAZY LIMESTONE.

The formation, which is so well displayed in many parts of the Champlain Valley, does not occupy a large area in Chittenden County. So far as has yet been discovered, it is only found in Charlotte, and a short distance south of the road leading from the railroad station in Charlotte to McNeil's Point, somewhat more than a mile from the station, there is a small outcrop of chazy and farther south on both sides of the road leading to Thompson's Point there is a larger area. This is a long narrow space, as shown on the map, Plate XLIXa. As shown on the map, there is a much more extensive development of the chazy about Ball's Bay a little farther south. Here south of the Little Otter the shore is entirely formed of chazy rock.

In the 1861 Report we find the statement that "At Charlotte the shore south of McNeil's Point is mostly composed of bluffs of chasm limestone." This is an error, for there is no chazy on the shore of the lake north of the Little Otter where it empties into the lake. South of this point the chazy comes to the shore, as we have noticed, for a considerable distance about Ball's Bay and farther south near Chimney Point. Nor is rock of this age found in large exposures inland, though it does appear in several places, but all are outside the territory here considered except that mentioned above.

It is probable that the beds at Cedar Beach, which are Trenton, and those at Thompson's Point, which have just been shown to be Beekmantown, were mistaken for chazy by the older geologists. On the map which is given at the close of Volume II of the 1861 Report the beds about McNeil's Point and Cedar Beach are correctly shown as Trenton, but those below at Thompson's Point are still set down as chazy. The area farther south through Addison County is incorrectly colored as all chazy. There are narrow patches of this age in the area indicated, but much of it belongs to other formations. The extent and character of the chazy rocks of Grand Isle and Isle La Motte have been considered in the two reports preceding this.

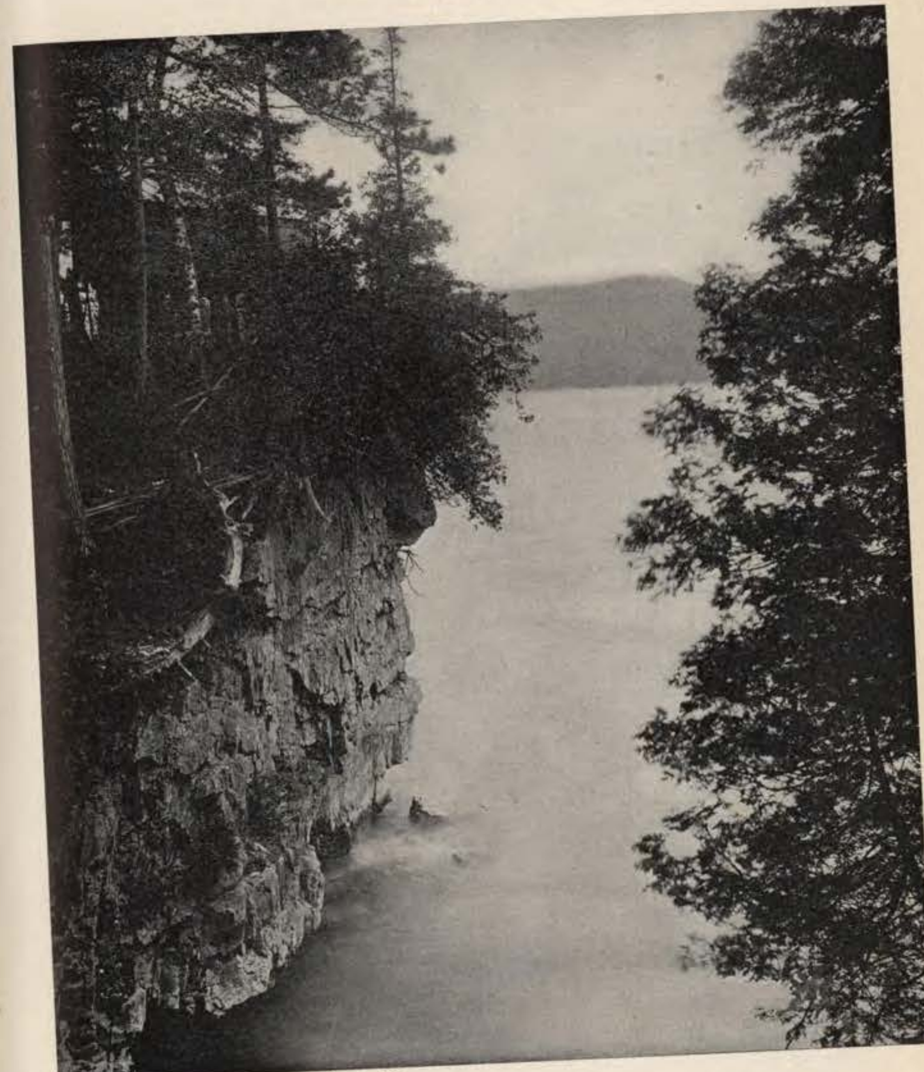
THE BLACK RIVER.

On the islands named above there are, as shown in the Fourth and Fifth Reports, areas of this limestone of moderate extent. None appears south of the outcrops at South Hero until we reach small areas of it in Charlotte east of McNeil's Point, east of the Trenton. The total area of this rock in Chittenden County is very small.

THE TRENTON LIMESTONE.

From some distance north of McNeil's Point, on south a short distance beyond Cedar Beach, the rock on the shore and for some dis-

PLATE L.



Negative copyrighted by B. Barker, Burlington, Vt.

Beekmantown Limestone Bluff, Thompson's Point, Charlotte.

tance east is Trenton limestone. This limestone is also well developed on the shore at several points almost as far as the southern end of Lake Champlain.

THE UTICA SHALE.

As has been shown in former reports, this formation occupies a large part of northwestern Vermont. The greater part of Grand Isle County and the northwestern portion of Franklin are of Utica. As these beds come into Chittenden County, they have become narrow and for the most part confined to the shore of the lake. It appears in western Colchester south of the Lamoille and extends along the shore to some distance south of Clay Point, where it disappears and is not seen again until it is found in Thayer's Bay not far south of Mallett's Head, except that, as was noticed in treating of the red sandrock, it underlies that rock at one or two places on account of overthrusting. Where there is rock along the lake shore it is all Utica from here south to Rock Point, where, as has been seen, there is a considerable outcrop under the sandrock.

At Colchester Point the shale is finely exposed and has evidently been very much disturbed. Appletree Point is also wholly of this shale. South from Rock Point the shale does not appear anywhere north of Shelburne Point. The whole of this point is made up of Utica, as are also Rock Dunder, Juniper Island and the Four Brothers in Lake Champlain. From an examination of these various areas it is evident that at the close of the Utica period the lake was filled with this rock at least as far over to the west as the western island of the Brothers, if the lake for a time was not entirely closed by these rocks, and there could have been only a narrow channel along the Adirondack shore. It is evident that the bottom of the lake between the present eastern shore and the Four Brothers and northward in a wide strip along this shore to the Canada line must be largely of this shale. Its depth is shown by the fact that in two deep wells near Burlington great thickness has been found. One of these in the city limits was bored through 120 feet of sand and clay and then 370 feet of shale, ending in this rock. The other well near the shore of the lake at Shelburne did not pass through the shale, though it went down 1,400 feet.

Of the great disturbances which occurred in the region now occupied by Shelburne Point we have abundant evidence in the very numerous dikes which are shown on Plate LII and briefly described

Many of the layers of the shale show slicken sides, smooth, shining surfaces, caused by movement of layer upon layer. I do not know of any locality where all this can be as well seen as at Rock Point at the place shown in the plate.

THE PLEISTOCENE.

In the previous report (pages 232–253) Professor Hitchcock, in an article on the Surfacial Geology of the Region about Burlington and the Champlain Deposits of Northern Vermont, has touched upon many of the features of the Pleistocene beds of this county.

In addition to these articles the present volume contains in Mr. Merwin's article on Shore Lines in Northwestern Vermont, other and very interesting observations on Pleistocene phenomena in this county as well as elsewhere.

Pleistocene geology must be largely surface geology and while the papers mentioned present many important and instructive discussions from which much may be learned of the Pleistocene in this region, there is much yet to be done in the same direction before all the problems met are solved and the entire history is clearly worked out. It is somewhat strange that nowhere in Vermont do we find any of the many beds that elsewhere intervene between the close of the Ordovician and the Pleistocene, but with the very slight exception of a small area of Silurian at South Vernon and a smaller of Devonian at Owl's Head on the Canada line, no bed or layer of any rock that can be placed between these far apart extremes has ever been discovered in the state except the Tertiary of Brandon, a small, but important deposit, which has been fully described in the two reports preceding this. What records there may have been which have wholly disappeared during the numberless years that must have come and gone between the Ordovician and the ice age we may never know. We simply know that if any there were we know nothing of them.

Borings for the deeper wells in various parts of the county show that not only are there heavy deposits of Pleistocene clays, sands, gravels, etc., rising above the general surface, but that in many places the same beds lie deep below it. In boring for some of these wells several hundred feet of these materials have been passed before rock was reached.

The supposedly Cambrian rocks shown at Winooski Falls in Plate XLV are overlaid a short distance back from the river by beds of brick clay, which are more than a hundred and fifty feet high and as may be learned by reading the articles above mentioned, such or similar deposits occur frequently in this county.

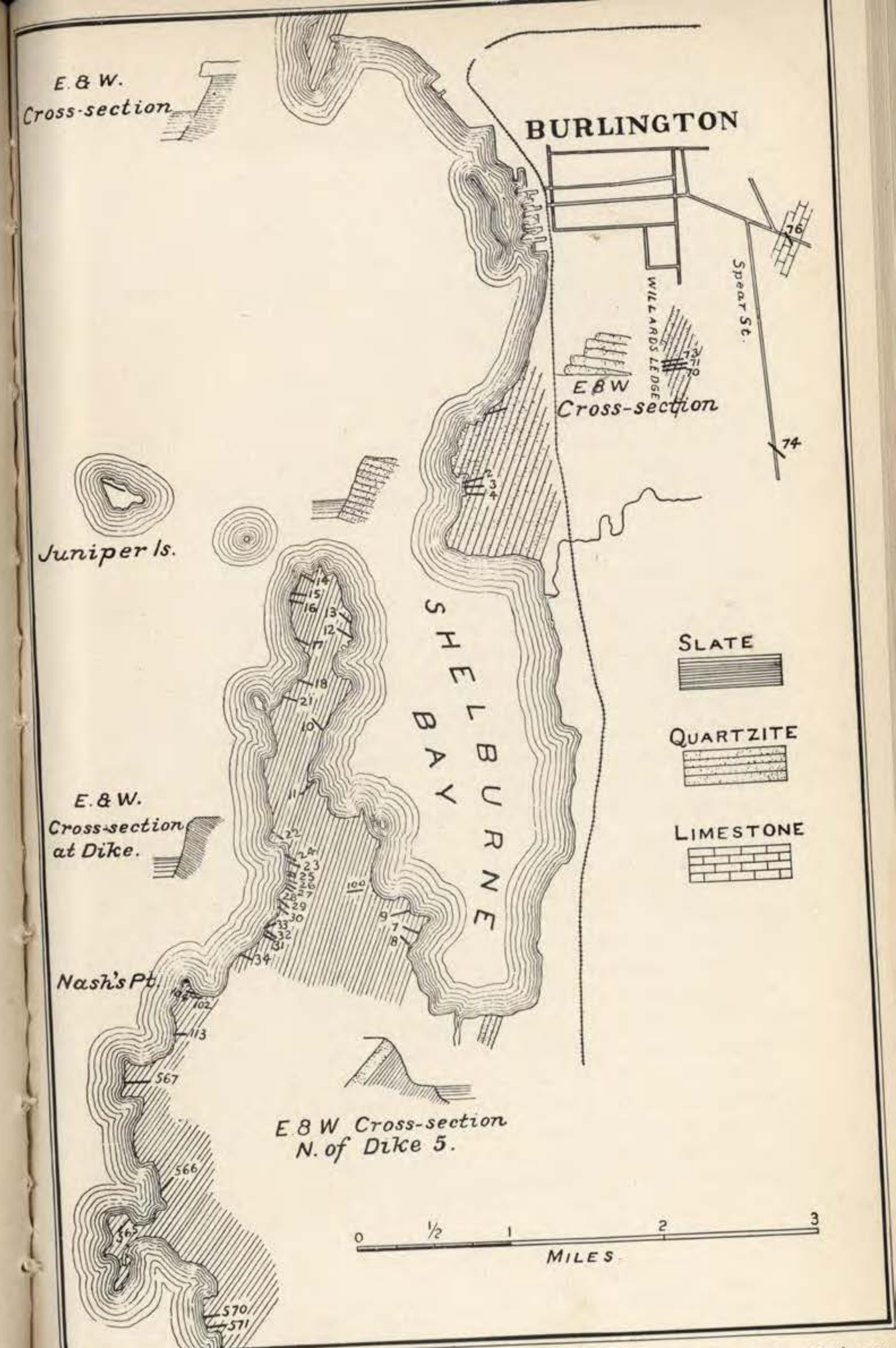
Old sea beaches are very common and bands of clay filled with white shells are not seldom very noticeable. Most commonly in this county these shells are of three sorts, viz.: *Macoma balthica*, *Saxicava rugosa* and *Mya arenaria*, and these sometimes occur in great profusion. Other species are found, but only on rare occasions. In a bank near the shore at Mallett's Bay, where the Cambrian sandrock has been carried out and Pleistocene clays and sands have come in, Mr. Griffin has this summer found the following species, four of which have not been found in this region, though common in Canada:

Leda minuta, Mull.
Macoma balthica, Linn.
Mytilus edulis, Lam.
Saxicava arctica, Linn.
Yoldia obesa
Macoma proxima, Br.
Mya arenaria, Linn.
Nucula tenuis, F. & H.
Saxicava rugosa, Linn.

Besides these there are small fragments of what appear to be echinoderm spines and plates, but they have not yet been clearly identified. The poverty of the Pleistocene beds here is in marked contrast with the much larger number of species found farther north in the Canadian clays. Somewhere between the northern border of the United States and the middle of Canada there must have been a great change in the condition of the later Pleistocene ocean; probably it was much deeper to the north and the water may have been otherwise different. Dr. Dawson, in *The Ice Age in Canada*, gives a list of 219 species, representing all of the greater groups of the animal kingdom, while Vermont has only afforded thus far the few species given above and the rest of New England can add little to it. If we may judge from the results of careful search made this season in a single clay bank, we may expect substantial additions to our list as a result of more extended and careful investigation.

IGNEOUS DISTURBANCES.

There are numerous evidences that Chittenden County has at some time been the scene of volcanic activity. What are called dikes are met frequently as one traverses the ledges. One of the best examples of these dikes is that shown in Plate LIII, which shows a very well



Map showing position of Dikes south of Burlington and about Shelburne Point. Drawn by Professor J. F. Kemp. From Bulletin 107, U. S. G. S.

defined one which cuts through Willard's ledge south of Burlington. This has since been much of it quarried away and used as road material. Most of the dikes in this region are small, only a very few feet across, but occasionally they are larger. Some are only a few inches across. Professor Zadock Thompson in the Appendix to his Vermont first called attention to the dikes of this region. Later in the Vermont Geological Report of 1861 a much more complete account was given by the same author.

So far as I am aware, nothing further was published concerning these phenomena until in 1893 Professors Kemp and Marsters visited the region and spent some weeks in studying its volcanic intrusions. Bulletin of the United States Geological Survey, No. 107, gives the results of this investigation and Plates LII, LIII are reproduced from this paper by permission.

During the past two seasons in our investigations of the ledges of the county we have come upon a considerable number of dikes hitherto unrecorded. As it is only within a few years that the classification of igneous rocks now adopted has been known, the older descriptions use the old names. Thompson classified all dikes as trap or porphyry in his earlier writing, but later he speaks of "Trap, Feldspathic and Porphyric," and gives the number examined as sixty, all in the western part of the county. In general appearance the dikes of this region differ, and still more in composition. Only a few have been studied either chemically or microscopically, and until this is done for all, our knowledge of them must remain incomplete, as in no other way can they be really known. They are quite unevenly distributed through the county and grow less numerous as we go from the immediate vicinity of the lake. Within the limits of the town of Burlington there are at least thirteen, in Shelburne twenty-five, Charlotte five, Williston four, Milton one, Hinesburg one, Colchester twenty-two, St. George two, Essex one, Richmond one. As seen by the above, Shelburne is most abundantly supplied with these intrusions and there must have been vigorous activity in the surface of the region about Shelburne Point when these dikes came up through the existing strata as molten intrusions from below. The map given on Plate LII shows how what is now Shelburne Point was rent and cut into by these intrusions. There are a number of dikes that occur in the region not shown in the map. North of Burlington there is not a large number of dikes, at least not as many as occur south. Yet there are quite a number in Colchester and Milton.

Commencing at the north border of Chittenden County and going southward, the first dike that is met is that at Fox Hill in Milton, which cuts through the Cambrian strata. This dike is about four feet wide. South of this place near the farm of Mr. Johnson is a somewhat smaller dike which is rather less than three feet across. At Colchester pond there is a dike three feet and a half across and another south of Day Brook which is three feet across. On the Wilson farm west of Colchester there are two dikes. The northern one is not very clearly defined, but appeared to be about twelve feet across. Not far south of this is another about two feet across, and a short distance southwest on the Blakely farm there are three more. These latter are not easily measured, being decomposed, the walls not distinctly defined and the soil covering them.

Farther south, on the south side of Sunderland Hollow, there is an extensive, but greatly obscured mass of dike material. The limits of this were so concealed by the soil that I could not determine whether there is here a very large dike or an overflow from a smaller one. The dike rock is very much broken and mixed with soil, but evidently there is a good deal of it. East and south of Sunderland Hollow at a quarry from which much limestone has been taken for making roads at Fort Ethan Allen, there is a dike four feet wide, and coming into the limits of Burlington, there are two dikes cutting the siliceous limestone in a quarry, from which road material was taken, situated just below the north side of Green Mount Cemetery.

These are not quite parallel, but both run in a northwest and southeast direction. They are about thirty feet apart. The more southern is thirty-three inches and the other thirty inches wide. The rock through which they come is probably Cambrian. The material is the same in both and appears to be bostonite.

There appears to be some mistake in Thompson's account of the dike at Hubbell's Falls, Essex Junction. Thompson speaks of this as "exhibiting several faults," and also says that it is "seen in the bed of the river," and gives a little map of the place, including the dike.

I have made several visits to this locality and cannot make out anything very much like what is given in Thompson's figure 313 of the 1861 Report. Instead of a twice faulted dike running in all parts nearly north and south, there is a very evident dike of diabase which may be first seen just below the old mill. From this point it runs northwest about 30° west of north, in a nearly straight line for several rods, cutting through the greatly disturbed slate. It enters the river and then very soon turns and runs back into the high north bank in an almost due north direction. Its course is a little west of north, but only a very little. The bank is thickly strewn with fragments of mostly limestone, and this and the clay from the bank wholly conceals the dike, except near the river. There is a dam some forty rods below and of course the water is set back by this. I could find no dike in the bed of the stream, nor any faulting, but it is possible that fifty years ago when Thompson wrote some part of the dike could be seen in the river. Still I cannot see how it could ever have been as described by Thompson.

As has been shown, the limestone and slate meet here and the dike is partly in slate and partly in limestone. I could not find any true faulting, but there may be a fault in the river, if the dike is there. Going back to the lake shore, as one comes from the north line of the county, the first dike met is a singular faulted one at Clay Point. I know of none other like this in the region. The dike cuts through the shale that forms the lower half of the Point and is ten or twelve inches wide.

It is faulted in the shale and the ends are separated about three feet. The undisturbed condition of the dikes of the region is noticed by Kemp in the bulletin, to which so frequent allusion has been made, and he considers this "a fact of great importance."

South of Clay Point, not far from the entrance of Malletts Bay, there are four dikes quite near together. The first of these is not easily measured. The next is about a foot in width. The next five feet and the last about a foot. Around Eagle Rock on the north shore of the bay is a dike three feet wide and farther on near Malletts Creek there are two more, one twenty-three feet and the other six feet wide.

South of this bay there are none on the shore or in the immediate vicinity of the lake for five or six miles. The first met are those at Willard's ledge on the Shelburne road. Plate LIII shows the largest dike at this place as it was several years ago. The strata here are cut by three other dikes besides that shown in the plate. The most northern is easily overlooked, as it is mostly concealed by soil and is in a part of the quarry not much worked. It is only

12 inches wide. Five or six feet south is a second similar dike about 22 inches wide, then some rods farther south is a third which is 30 inches wide and that figured in the plate is only a few feet farther south. This last is quite irregular. At the west end it is 12 inches wide, but presently it divides and, apparently, is split into a double dike which crosses the quarry. In places the two parts are five or more feet distant, one part being 24 inches and the southern is 10 inches. Before they are half across the quarry they unite and after forming a single dike for several rods they again separate, increase to a width of about three feet each and run into the east wall, separated by a few feet of the sandrock. Thompson mentions only one dike at this place and it is possible that in his day, over fifty years ago, the surface soil concealed all but the one he noticed. He says: "The trap dike that cuts through Willard's ledge is two feet and a half wide at the brow of the ledge. A few rods to the east it reappears and is there four and a half feet wide. It is then covered, to reappear about a fourth of a mile farther east." Professor Kemp considers these Willard's ledge dikes all augite-camptonite. Speaking of the dike shown on Plate LIII, as it was when he photographed it, 1890, he says: "Reproduced from a photograph is a view of No. 70 from the east, the quarry having been worked out from behind it. The dike is five feet thick and is exposed for 200 feet. It is a typical augite-camptonite." This dike, as shown in the plate, has been entirely quarried away, but as the quarry has been worked other portions have been exposed, so that there is now a western front that very closely resembles that shown in the picture. Several acres of the ledge have been taken out since Thompson saw it, and even since the view given was taken a large amount of stone has been removed, but the dikes are still very evident. At the time Professor Kemp visited it, we found the dike reaching like a great wall across the quarry, the sandrock having been quarried away, leaving it splendidly shown. This wall has long since gone upon the streets. East of the city of Burlington there are several small dikes as shown on the plate, except that there are more than those shown. On the Williston road just beyond East Avenue there is one thirty inches wide (by misprint this is given in the bulletin as six to ten feet). The rock through which it cuts is a gray siliceous limestone. This is No. 76 of Plate LII. About a mile or less south of this on Spear Street is another dike two feet wide, and a hundred feet farther south a third five feet wide.

Dike at Willards Ledge, Burlington. From Bulletin 107, U. S. G. S.

The latter is 74 of the map, the other is not shown. Passing east and crossing Muddy Brook there is a dike four feet wide in the red sandrock. Another cuts through a shaly rock in Williston on the east side of the brook.

Coming back to Willard's ledge and going south a mile or so one comes to a great mass of red sandrock known as Red Rocks.

Following the shore of the lake, the first dike reached, No. 1 of Plate LII, is of especial interest, as it is of material unlike that hitherto found in those mentioned, being a monchiquite consisting of olivine, hornblende, augite, biotite and a glassy base. It is a foot to a foot and a half wide.

Following the shore for some distance south beyond Oak ledge, we come to three rather large dikes which are not very distant from each other. These are shown on the plate as 2, 3, 4. Above these is a small dike which Kemp gives as twelve to eighteen inches wide. This is near No. 2 of the map, is thirty inches wide and is like the others monchiquite. The next is probably Thompson's, No. 3, which he speaks of as a "broad dike twelve feet wide, situated only twenty feet from a feldspathic dike six and a half feet wide and running parallel with it." There is some mistake in these notes, for there are not two dikes of this size at this locality or near it. It is possible to account for the twelve feet wide one if we suppose that Thompson measured not the actual dike but the cut in the sandrock where it went into the lake long ago. The dike has been broken out for a distance of thirty or forty feet and there is a gash or channel in the sandrock where it formerly lay. A boat can now be pushed into the little harbor between the smooth vertical walls. At the Lake these walls are about twelve feet apart, but the dike rapidly narrows as it goes in so that at the present time the width is, as Kemp states, six feet. It is also possible that Thompson's next measurement may be explained in the same way. This dike, 4 of the map, is peculiarly broken. It is cut away from the enclosing sandstone like the preceding, but to a less extent, the channel in the rock being about twenty feet.

Nearer the water it was undoubtedly over six feet wide, but as it is now it is not more than three and a half feet. At the outer end this dike is divided. The northern part soon runs out, but the other continues into the cliff and is over three feet wide at the bottom, but as it rises in the cliff, which is here nearly vertical and some thirteen feet high, it grows narrower. All of these appear to be monchiquite.

Following the cliffs around Red Rock Point and going on east for about a third of a mile, there is another dike, apparently not seen by Kemp, as it is not indicated on his map, Plate LII. It is, however, noted on Thompson's map, Plate XIV (wrongly numbered X). This dike is quite unlike those to the north of it in character and appearance. It is a pinkish brown porphyry and very much decomposed. Indeed the surface is deeply covered by a mass of nodular masses mostly about as large as one's fist. These lie along the very steep face of the dike, as if material for macadamizing a road had been thrown there. It cuts through the high cliff near what is called Flat Rocks in the Red Rocks Park. At the Lake its face is quite concealed by willow bushes, so that one passing in a boat would not suspect its existence. In the lower part it is twenty feet from wall to wall, but grows narrower as it rises in the cliff. The adjacent rock is considerably disturbed and shows that it has been much heated. Along each side between the dike rock and the sandrock through which it has cut its way there is a curious layer of conglomerate of white quartz pebbles, five or six inches thick. This dike may be located on the map as a little west of the brook (Potash), which is shown not far east of the quartzite at the north-eastern shore of Shelburne Bay.

Another dike, also, not noted on the map, is not on the shore, but is exposed a few rods inland, perhaps fifty or more. It is north and a little east of the dike just mentioned. It cuts through the red sandrock and is seven feet wide. These two dikes, therefore, should be added to those marked on Plate LII, as well as those previously mentioned, viz., a second on Spear Street a few rods south of 74 of the map, and a fourth in Willard's Ledge a few rods north of 73.

It is very probable, as Professor Kemp has suggested, that somewhere in Shelburne Bay there is a fault, for on the north side of this bay we find only Cambrian sandstone, and on the south only Utica shale.

The former continues from Red Rocks around to the south end, where it ends in a low outcrop even with the surface.

Disturbance appears to have been confined to the south side of the bay, for here we find, as Plate LII shows, numerous dikes, while there are none on the north shore. Shelburne Point is a narrow tongue of shale about three miles long and in this distance it is cut and slashed by no less than twenty-eight dikes. A glance at Plate

LII shows how frequently the shale has been broken into by the volcanic rock.

These dikes vary in width from six inches to twenty feet. Most of them are several feet wide.

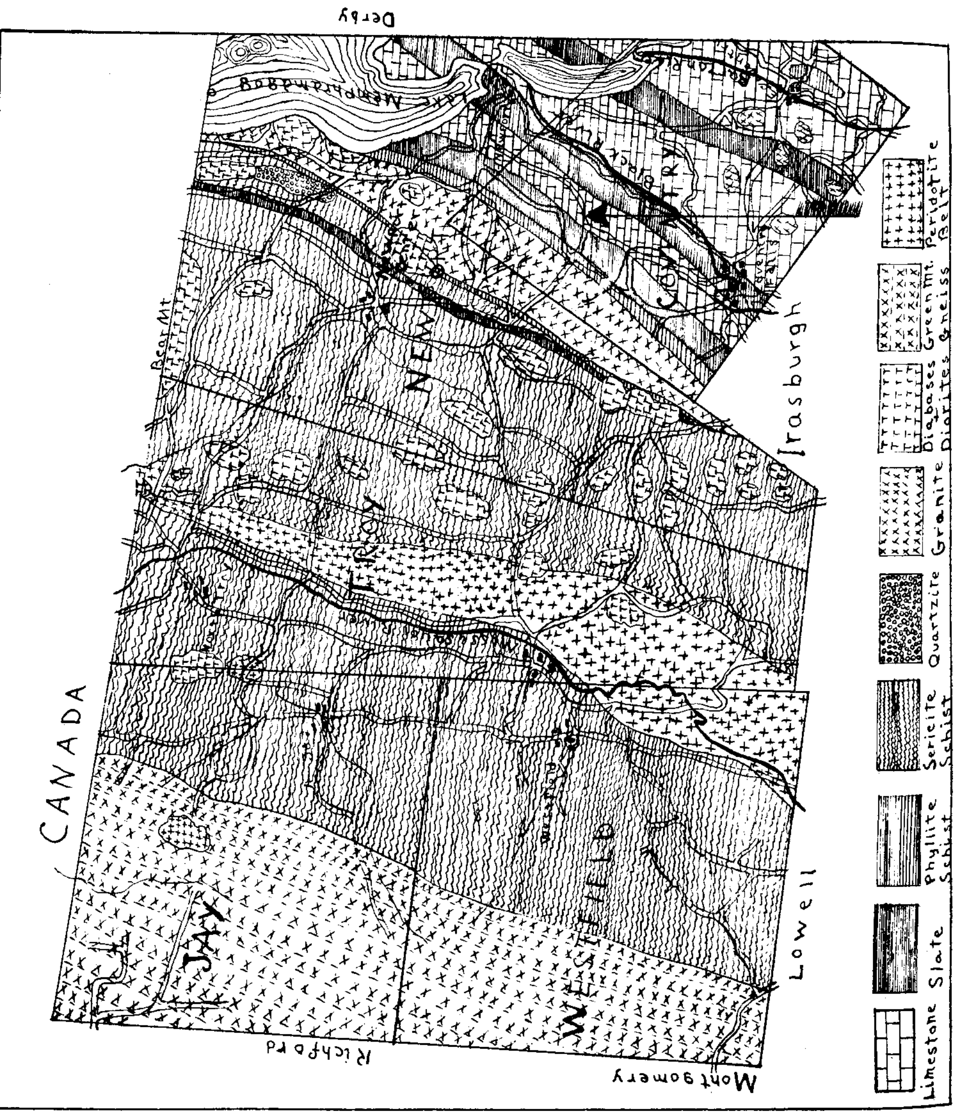
While the direction varies somewhat, most have a strike northwest. As determined by Professor Kemp, the greater number are bostonite, half a dozen are monchiquite, and three augite-camptonite. Kemp speaks of these dikes as follows: "Two very peculiar dikes on Shelburne Point are met with not far from the foot of the bay. The southern one is a yellow bostonite and the northern a breccia bostonite. This latter, No. 7, is without doubt continuous across the Point and appears as No. 29 on the west side. Dike No. 9 of the map is on the outcrop merely a seam of limonite. No fresh material could be found on the surface. The outcrop looks like a vein of ore, but we believe it to be a weathered dike. On the highway is a dike, 100, a bostonite, but its width and strike are not distinct. Following the shore north, No. 11 is porphyritic bostonite. No. 1 is undoubtedly continuous with 21, and consists of idiomorphic, brown basaltic hornblende and a little augite in a ground mass of augites of the second generation, and glass.

The dikes on the end of the Point, 12–18, are all basic and exhibit alternations between rocks with plagioclase and rocks without. Nos. 17 and 18 have plagioclase and are camptonites. All the others lack it and present beautiful idiomorphic hornblende and augite in a glassy base, that in No. 14 gelatinizes. Olivine is present in all. They are, therefore, monchiquites." A little south of Shelburne Point is Nash Point. This is a rather broadly triangular point and has three dikes on the north side and one on the south, while the entire end is formed of an interbedded sheet of intrusive matter. According to Kemp: "It is ten feet thick and follows the southeast dip of the slates. It is abundantly set with slate fragments and the slates at the bend are much broken and crumpled. The most interesting feature is that the sheet cuts two basic dikes, one of which can still be traced in the thin cap of overlying slate. The basic dikes are then older than the sheet of bostonite. The basic dikes consist almost entirely of zonal augite. Southward on the shore a great forty-foot dike is exposed, but as its walls are not well shown its relations cannot be clearly made out. It is bostonite with very large phenocrysts.

South of this greatest of the dikes of this region there are at intervals as one goes along the shore, larger or smaller dikes. These are from one foot to ten feet wide and are more often bostonite. Just before reaching Wings Point there is an eighteen-foot dike of bostonite, but just before this is one of camptonite. On Thompson's Point there are two dikes and so far as I know there are none south of this point for a considerable distance.

There is a small dike, about a foot and a half wide, that crosses the north end of Juniper Island, appearing on the east and west shores. The knob or low hill not far south of the railroad station at Charlotte has long been known as a mass of intrusive rock. Professor Kemp says of this: "At Charlotte, a station twelve miles south of Burlington, a knob of bostonite is found which covers about twenty acres and rises a hundred and fifty feet above the plain. It is elliptical and overgrown with woods. The exposed material is not fresh, but shows a porphyritic structure with red and white feldspars."

In the town of Shelburne some distance east of the Point there are several dikes. One is not far west of Shelburne Pond. This is about a foot and a half wide and cuts through a bed of siliceous limestone. West of this is a larger one about five feet wide which cuts through a bed of white marble. Still farther west, near the Laplat, is a dike four feet wide, cutting the sandrock. A mile or so east of northern dike is a large one, being over twenty feet wide, while the Shelburne village are two dikes only about thirty rods apart. The other is eight feet wide. Both cut through siliceous limestone.



The Geology of Newport, Troy and Coventry.

C. H. RICHARDSON, SYRACUSE UNIVERSITY.

INTRODUCTION.

The present report upon the Geology of Newport, Troy and Coventry, Vermont, is of necessity brief. It must be considered only as one of progress. A few weeks in the summer of 1907, together with an equal amount of time in June, 1908, comprise all the time that has been available for the study of the field relations, the mapping of the area involved, and the collection of typical museum specimens. This amount of time has proven even too limited for the scaling of every hill and the discovery of all possible exposures.

The area chosen comprises three townships in the northern part of Orleans County, west of Lake Memphremagog and south of the International boundary. Some work has also been done in Derby, Brownington, Barton, Irasburgh, Jay and Westfield. I am in hope that enough field work can be accomplished within the following two years to enable me to complete an article upon the geology of the entire county for the next report of the State Geologist.

Several photographs have been taken, a part of which appear as half-tones in this article, while the others are reserved for future illustrations. One hundred and eleven new rock specimens have been collected in the field from northeastern Vermont, carefully trimmed to standard uniform size, 3 x 4 inches, making three hundred and thirty-three specimens, and placed on exhibition in the State Museum at Montpelier. These specimens represent a series of very important rocks of widely different ages, mode of origin and chemical composition. When the series is made complete it will form a valuable educational factor in illustrating the geology of eastern Vermont.

Two maps accompany this report. One is stratigraphical, representing a protracted section across Newport, Troy and Coventry.

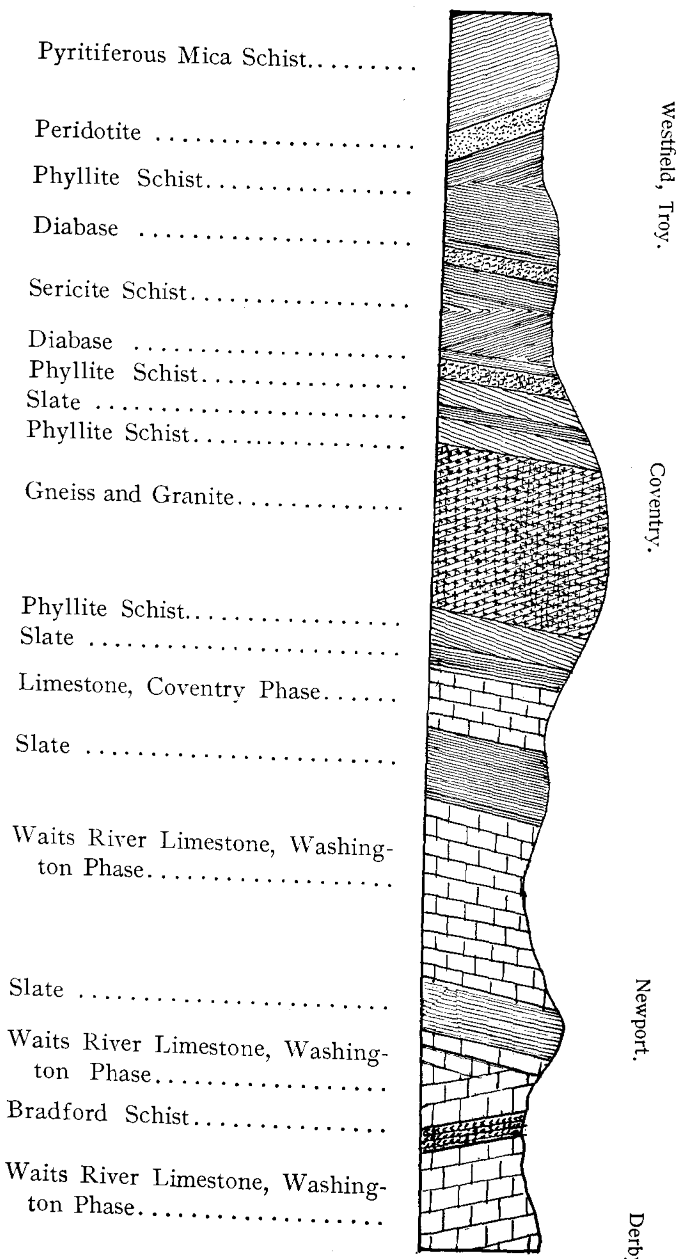


Figure 6.

Section from Westfield to Derby.

The other shows the geographical distribution of the terranes within the same area. The stratigraphical map reveals the dip of the strata whose planes of cleavage do not always coincide with the planes of bedding. No bibliography is herein given because a complete bibliography was printed in the Fifth Report of the Vermont State Geologist, 1906.

I wish also to recognize my great indebtedness to Prof. John A. Dresser, McGill University, Montreal, for his timely assistance in the study of these rocks in better developed Canadian territory, in the Black Lake district northeast of Sherbrooke; to the Canadian survey for effecting arrangements for international coöperation in the work of the two surveys most deeply interested in the problems; and to Burton W. Clark, a graduate student in Syracuse University, for his companionship and aid in working out numerous details in the field for twelve days in June, 1908.

DRAINAGE.

With the height of the land twenty-five miles south of the international boundary, the drainage of the area described in this report is naturally to the north.

Barton River, with its head waters in Crystal Lake in Barton, flows through the eastern part of Coventry and empties into Lake Memphremagog. Along this river the Passumpsic division of the Boston and Maine Railroad threads its sinuous way into Newport, where it makes connection with the Canadian Pacific Railroad for Montreal.

The Black River rises in Craftsbury and flows northward through Irasburgh, Coventry and Newport into Lake Memphremagog. As will be seen in the discussion of the geology of the area, each of these streams lies in a bed of limestone with a belt of slate, hard and pyritiferous, rising to a much higher altitude between the valleys.

The third river of noteworthy dimensions is the Missisquoi. The source of this stream is amongst the mountains of Lowell. It is fed also by numerous branches from the western slope of the Green Mountains in Jay and Westfield. In its northward course through Troy it furnishes some of the best water powers of the state. Great Falls on this river, about two miles south of North Troy, furnishes an excellent example of such power. Through this valley there is also an easy outlet for the proposed Mount Orford Railroad in its connection with the Burlington and Lamoille road. This would prove a very important factor in the economic development of the asbestos and iron industries of Eden, Lowell and Troy.

TOPOGRAPHY.

The area traversed lies practically between parallels 44° 50′ and 45° north latitude, and longitude 72° 10′ and 72° 25′ west of Greenwich. It therefore comprises an area of about 140 square miles.

The valleys are principally longitudinal, whose direction was somewhat determined by the harder and more resistant bands of slate interstratified with the Lower Trenton limestones of Newport and Coventry, and by the intrusive masses cutting the older sericite schists in Troy. The transverse valleys are all small and of minor importance. The latter have been produced by the corrasion of the smaller streams, while the former are effected by the foldings of the Cambro-Ordovician and Lower Trenton terranes.

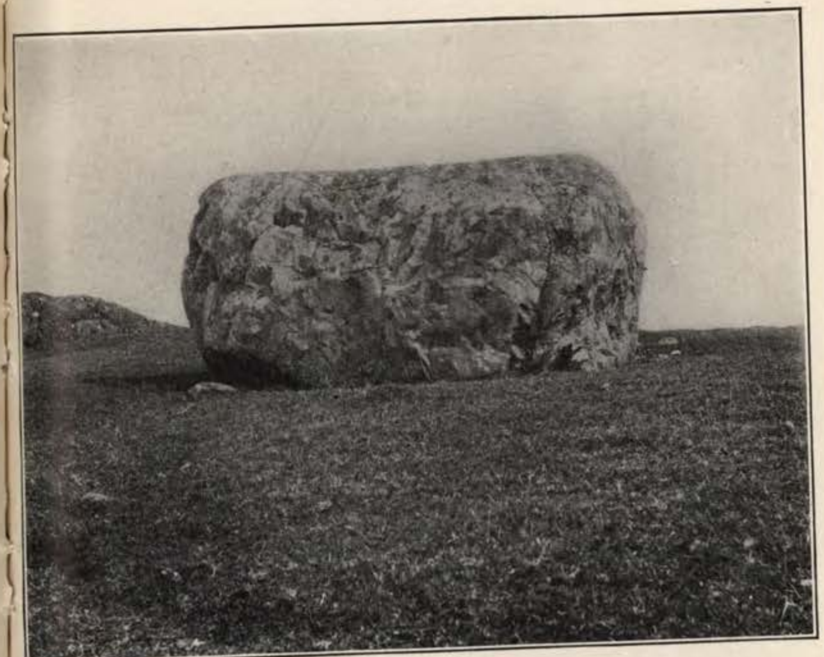
The valleys in the limestone have been cut down to an altitude varying from 650 to 800 feet. The belts of slate between them rise to an altitude of 1,000 to 1,100 feet above the level of the sea. The highest altitude observed was on the Black Hills in the southern part of Newport, approximately 2,000 feet. Yet to the immediate west in Jay and Westfield, Jay Peak rises to the height of 4,018 feet. The village of Newport is at the B. & M. station 688 feet above sea level.

GLACIATION.

The three towns considered in this report are mantled with morainic material to such an extent that the geologist may travel many miles in the direction of the ice movement without finding a single outcrop of rocks for the study of field relations. This holds especially true in the broad U-shaped valleys south of Lake Memphremagog. Also true on a line south from Bear Mountain through Newport. This latter field is so highly mantled with glacial debris that Prof. C. H. Hitchcock in his geological maps of Vermont thought it advisable to catalog no terranes within the area.

It is only therefore by following through each ravine and wooded slope that enough rock exposures have been found to warrant the mapping of Cambro-Ordovician rocks within such areas. In the vicinity of Newport, where the rock masses are the least disturbed,

PLATE LV.



Boulder of Pre-Cambrian Rock resting on Trenton Limestone, Irasburgh.

this debris, modified by post-glacial rivers, is often hundreds of feet in thickness. This mantle most seriously impedes progress in investigation and may conceal the true diagnostic features of age.

The general trend of the ice is well known to be southeasterly. By following in a northwesterly direction we may trace many interesting erratics back to their parent source. Syenites not known to exist in northeastern Vermont save in boulders, have led men to search in vain for a black granite amongst their forest-covered hills.

Plate LV shows a large boulder of pre-Cambrian rock resting on Trenton limestone at Irasburg.

Boulders of the old Lawrentian gneiss from the north side of the St. Lawrence River are strewn along the pathway of the ice. The most interesting spectacle of all is represented by Plate iv, which shows a large boulder of Pre-Cambrian material resting upon Lower Trenton limestone in Irasburgh. No other large boulder can be found in the entire neighborhood. The symmetry of the rock together with its isolation makes it an object of considerable interest.

Not only have the longitudinal valleys been broadened and deepened, but many of the smaller transverse valleys have been partly filled by glacial debris, and, therefore, given rise to numerous small ponds scarcely worthy of the name of a lake. Between two of these ponds in the northwestern part of Coventry, Bowley's and Daggett's, there is a fine esker about a quarter of a mile in length. With its characteristic rolling surface, this water-laid morainic debris becomes very striking.

Another feature of the work of the ice is manifested in many areas. The exposures of the youngest intrusive, the diabases, have been rounded and polished until they suggest haystacks in some localities, and in others roche mountainee.

LAKES.

But one lake of sufficient size to be worthy of the name of a lake lies within the area covered in this report. Lake Memphremagog, stretching itself from Coventry Bay through Newport into Canada for a distance of 40 miles, covers an area of 48,000 acres, of which 9,600 are in Vermont. The lake is 686 feet above sea level. Its bed is in part in black and gray graptolitic shales and limestones of Lower Trenton age; in part in Devonian granites, as is manifested along the eastern shore in Derby, and in part in Canada in Devonian limestones, as at Owls Head and Georgeville, Province of Quebec.

Strange as it may seem, isolated patches of tree-covered slates and limestones stand out as islands in the midst of the lake, while others are in part limestone and in part granite.

The lake is scarcely surpassed by any waters in its scenic beauty. Intrusive mountains of diabase rise on its western slope to over 2,700 feet, while the hills on the east gradually die away at lower altitudes.

GEOLOGY.

The geology of northeastern Vermont is intricate and complex. The terranes consist largely of a series of crumpled, folded, faulted metamorphic rocks, dipping always at high angles, and often cut by intrusive masses. In the western part of the area covered by this report stratigraphy must be determined by field relations, and even then there is a wide chance for error. In the eastern part of the field it has been my good fortune to discover two beds of limestone carrying marked evidence of crushed graptolites. This new feature will be discussed under the caption of Paleontology. It is believed that here lies the true diagnostic feature of age. The problem simplifies itself somewhat in the eastern part, but remains complex in the western.

A.

PRE-CAMBRIAN.

The introduction of the term Pre-Cambrian here is only to anticipate what properly belongs to the next report, which will doubtless include the western part of Orleans County. It comprises the major anticline of the Green Mountains and extends from the international boundary southward through Jay and Westfield, which carry the highest peak of northern Vermont, Jay Peak, 4,018 feet above sea level.

The anticline consists of the Green Mountain gneiss flanked upon either side by a series of highly metamorphic schists. It is only the schists upon the eastern side with which this report is concerned, and even then a belt of altered sedimentary rocks five miles in width must be traversed before the crest of the anticline is reached. This field lies almost entirely in a forest-clad area, which adds to the many difficulties of determining stratigraphical relations.

One line only was run through Jay to its western border in June, 1908. For this reason the map, Plate LIV, is for the townships of

Jay and Westfield after the reports of Prof. C. H. Hitchcock. Some two miles west of the Jay line there are numerous outcrops of the peridotite belt, which have given rise to fine samples of asbestos. Their location on the map awaits the necessary field work for the re-mapping of the area.

B.

CAMBRO-ORDOVICIAN.

This term as here used for the first time in my report signifies an undivided group of highly metamorphosed sedimentary, or metasedimentary, rocks lying between the eastern foothills of the Green Mountains and the valley of Lake Memphremagog. They consist of pyritiferous mica schists, sericite schists, chlorite schists, quartzites, slates and gneiss. Their general strike is N. 40° E., while their dip varies from 70° E. on the west to 80° W. on the east. In them, therefore, we find two synclinal troughs and one anticlinal axis not comparable to the major axis of the Green Mountains.

These terranes have long been considered by Prof. C. H. Hitchcock of Dartmouth College and by the earlier Canadian Geological Survey as Pre-Cambrian. The finding in them of sedimentary rocks that appear to be Cambrian, and others that by stratigraphical position may be later, the author has chosen rather to lift this complex series out of the category of the more ancient terranes and place them as Cambro-Ordovician. However, if sufficient time could be given in the field to trace out the details of the relation of the quartzites to the more highly metamorphosed sediments, it might be found that in the mountainous and wooded area of southern Newport even Pre-Cambrian rocks exist. Further field study would be required to settle the question.

a.

MICA SCHISTS.

The pyritiferous mica schist is best seen to the west of the village of Troy. Large crystals of sulphide of iron, FeS_2, have dissolved out, leaving many cavities in the decomposing schist. Single hand specimens sometimes show a score or more of square holes formed by the complete washing away of these secondary products. These cavities are square because the pyrite was in the geometrical form of the cube.

Some of these chambers are filled with the oxides of iron, but in the surface portions the original sulphides do not appear. This chist carried also veins of a bluish quartzite with exposures often rounded and embossed by the action of the ice and now stand out in bold relief amongst the softer and more readily decomposing schistose rocks.

b.

SERICITE SCHISTS.

Flanking the pyritiferous mica schist on the east there is a broad belt of schistose metamorphics stretching southwesterly through Newport and Troy. These sericites are perhaps the most typical in development a little to the west of the village of North Troy, where its rift and grain is so perfect that it has been quarried and used locally for building purposes. In fact within the same village near the Missisquoi River it is exceedingly fine grained, and with its perfect cleavage strikingly suggests a slate.

It is through this series of sericites that the Missisquoi River now threads its sinuous way. It is through this also that the broad intrusive peridotite belt has appeared.

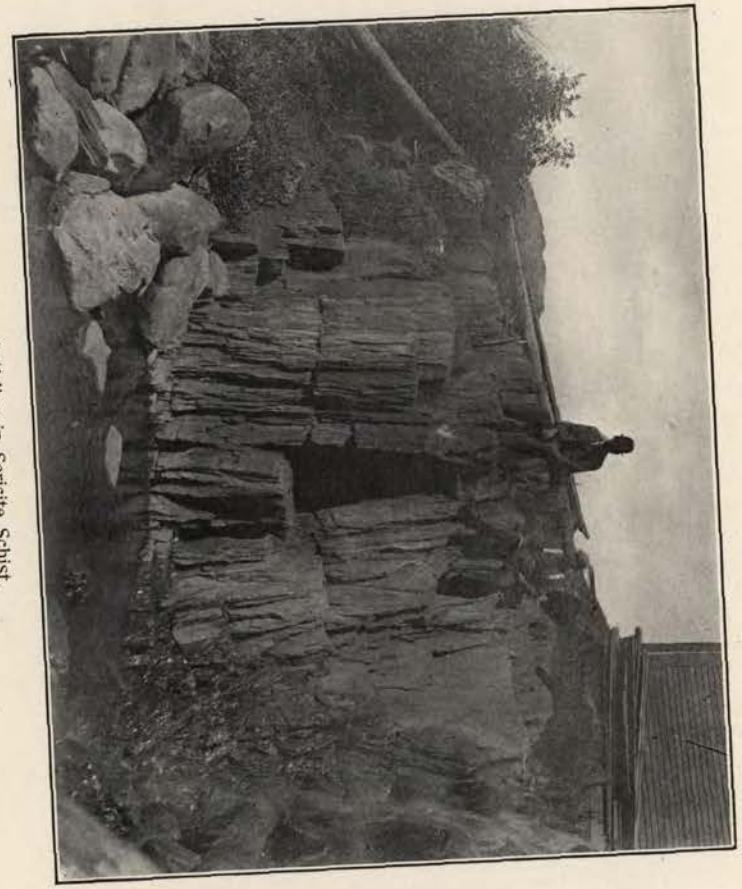
Along the Missisquoi valley these schists are the least disturbed. In the region of the Black Hills in the southern part of Newport, formerly called Coventry Gore, they are the most highly folded, crumpled and penetrated by numerous auriferous quartz veins, which have given rise to an active quest for gold in this vicinity.

This high degree of metamorphism in the more eastern and southern sections is not only due to changes that took place during the Cambrian Revolution of early geological times, but to intrusive masses of diabase and diorite at the close of the Devonian. These irruptives will be discussed more fully under the caption of intrusives.

In many sections these schists approach a quartzite and might be catalogued as a quartz schist. In such phases the parallelism of the minute scales of sericite is perfect and the whole mass seems to be made up of but little more than quartz grains held together by an original cement of clayey matter and iron. No attempt has been made to separate these siliceous areas from the more highly sericitic phases of the schist. They are simply regarded as representing the more siliceous sediments laid down on the floor of the ancient seas. Their meaning, however, may be far deeper.

Near the eastern border of these schists and yet to the west of the broad belt of gneiss and gneissoid granite, there stretches southward

PLATE LVI.



Anticline in Sericite Schist.

from the neighborhood of Bear Mountain a narrow belt of slatey material about 70 feet in width. It appears in the northern part of Newport under the eastern portion of Bear Mountain; again to the east of Newport Center; again to the south of the Burlington road from Newport to Troy; and lastly in the dense wooded area of the southern part of the township. Here its cleavage is highly perfect and the rock mass becomes a true slate. Here also it is cut by the intrusive diabase. The limited number of outcrops of this member, due to the deep mantle of glacial debris that overlies it, makes its true stratigraphical relation somewhat difficult to determine. It may represent simply the finest muds and silts of the same ancient sea. Plate LVI represents a sharp anticline in the sericite schists at Newport Center.

c.

PHYLLITE SCHIST.

Two narrow belts of phyllite schist traverse a part of the area herein covered. One is found occasionally flanking the broad belt of gneiss and gneissoid granite of Newport and Coventry on the west. The other lies to the east of the same belt. Each dips uniformly to the west. In the northern part of Newport they disappear altogether along the western margin of the lake. On the west it may be replaced by the more siliceous sediments.

The exposures of the fine grained phyllite schist are not many and everywhere they are badly decomposed. That they too have been cut by the intrusive diabase is well proven by samples collected showing the actual contact of these early sediments with the latest intrusive of the area, the diabase.

d.

QUARTZITE.

In the northern part of Newport, stretching about two miles south of the Canadian border, there is a belt of well defined quartzite about one-half mile in width. This quartzite overlies the northern portion of the gneiss and gneissoid granite belt. Its dip is uniformly to the west. Its strike is N. 30° E. It does not stretch enough to the south to be embodied in the structural section. Its characteristics in the field are somewhat suggestive of the Cambrian quartzite on the west side of the Pre-Cambrian Green Mountain gneiss which forms the major axis of the Green Mountains.

The presence of this quartzite has had its influence in leading the author to place the above series as Cambro-Ordovician, rather than to relegate them all to the Pre-Cambrian, where they have formerly been placed.

C.

WAITS RIVER LIMESTONE.

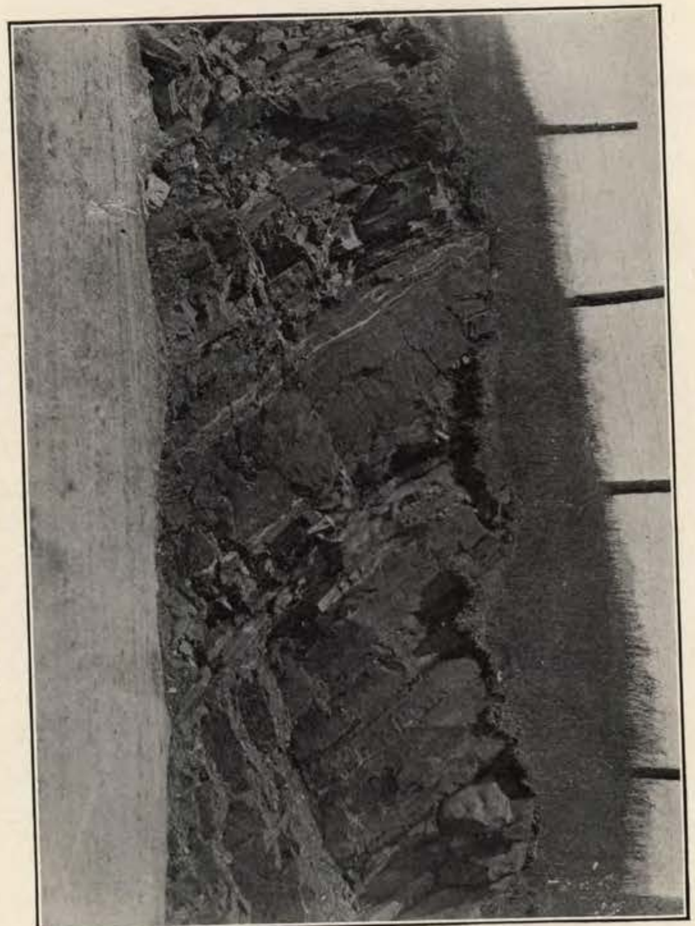
In 1906 this name was submitted to the committee of geologic formation names at Washington, D. C., and was adopted by that committee as an alternate for the preoccupied name Washington limestone, which was applied by the author of this report in 1895, to the calcareous member of the calciferous mica schist of previous reports by Prof. C. H. Hitchcock. The term Washington is no longer retained amongst geologic names in Vermont save only as it applies to the phase of the Waits River limestone, where it was first studied by the author and where it is best represented in Washington, Vermont.

The Waits River limestone, as previously described, falls into three distinct phases. The first of these, the beautifully banded variety, so closely resembling Columbian marble of Rutland, Vermont, does not occur within the area covered by this report. It does, however, appear ten miles to the east at Willoughby Lake in Westmore. The type locality is more than 75 miles to the south at Waits River in the township of Topsham, Orange County, Vermont.

The dark steel gray Washington phase appears in Derby, Brownington, Newport and Coventry. It is the principal geological formation in the eastern part of Coventry, but the area is comparatively small in Newport. It is lighter in color in the northern than in the southern portions of the state. Although the distance across two towns is scarcely adequate for great changes to occur, yet in the comparison of the light gray localities in Canadian territory with the uniformly dark areas in Danville and Washington the contrast becomes very striking.

It is in this belt that the great anticline in the limestone series is best seen. In Washington the limestone lies in horizontal position upon the crest of the anticline. In Derby the fold becomes quite sharp. Plate LVII represents an exposure of the limestone in West Derby with dip to the east of about 70° and strike N. 20° E.

PLATE LVII.



Outcrop of Waits River Limestone, West Derby.

After passing over this anticline in a westerly direction the dip is uniformly to the west. It is in this limestone that the broad U-shaped valleys of the Barton and Black rivers have been cut. In this limestone a zone of crushed graptolites in Coventry and Brownington has been discovered and will be discussed under the caption of Paleontology. In this limestone many Devonian granites of great economic importance appear. The well known typical Barre granite, the Woodbury granite worked at Hardwick, and the Newport granite quarried in Derby are amongst the best representatives. These granitic areas in Newport and Coventry will be further discussed under the caption of intrusives.

The third member is darker than the other two, more carbonaceous, sometimes shaley and never susceptible of a polish. It traverses Irasburgh, Coventry and Newport and dips uniformly in a westerly direction. Lying as it does at the foot of the western slope of the anticline, it is the youngest phase of the limestone series. I have chosen in this report to catalog it the Coventry phase of the Waits River limestone. The Coventry phase is so named because in Coventry it has its type locality and can be more easily observed here than elsewhere. Here it is uniformly dark in hue, often pyritiferous and compact.

It is separated from the Washington phase of the limestone by a broad belt of roofing slate. It is flanked on the west by another belt of slate in Irasburgh, Newport and Coventry. In the last named town it has been burned for lime, but never quarried for structural purposes like the other phases of the limestone series.

Prof. C. H. Hitchcock in his work on the Geology of Vermont, 1861, catalogued this phase as of Devonian age contemporaneous in age with the well known crinoidal limestone at Bernardston, Mass., which locality is on the opposite side of the great anticline of the limestone series more than 150 miles to the south of Coventry.

A small patch of Devonian limestone does, however, occur at the foot of Owls Head on the west side of Lake Memphremagog in which the typical diagnostic features are well preserved. A diligent quest for fossils in the Coventry phase has failed to discover the first trace of organic remains. Lithologically it more closely resembles the Washington phase of the Waits River limestone, which is quite definitely located as Lower Trenton than either the limestone at Owls Head or Bernardston, Mass.

One may not be justified in relegating this limestone to a lower position in the great geologic series without some diagnostic evidence of fossil character. Yet without the abundant evidence of Devonian fossils which abound in the other localities already cited, the author is prejudiced in favor of its true stratigraphical position being considered lower Trenton. However, it may remain for the present one of the unsolved problems, until some geologist in his good fortune discovers the true Devonian or Lower Trenton fossils. If it be Devonian then it lies as a shallow deposit in a trough of Lower Trenton slates.

It is worthy of note that the strike of all these terranes would carry the Owls Head limestone to the west of the great belt of gneiss and gneissoid granite rather than to the east where these rocks lie. In the area where Devonian limestones should lie, to the west of the gneiss, if represented at all, many angular masses of unquestioned Devonian material was found, but these could not be proven to be in place. Their direction was out of the trend of the great ice sheet, which, if a Devonian belt did not exist in Vermont to the west of the gneiss, must have been transported unbroken from the Canadian territory to their present habitat. The author is therefore inclined to believe that if all these possible outcrops in the low areas south of the eastern portion of Bear Mountain could only be thoroughly covered, this limestone would somewhere be found in place south of the international boundary.

D.

BRADFORD SCHIST.

The typical phase of the non-calcareous lower Trenton terranes does not appear in the area mapped in this report. There are, however, isolated patches more or less interstratified with the limestone that are devoid of lime. These occur as phyllite and ottrelite schists. They may be seen on the road from Coventry to Brownington in that part of Derby formerly known as Salem. Other areas are found in the hills to the west of Barton River in Coventry. Each of these localities is represented in the specimens collected for the state museum at Montpelier.

E.

MEMPHREMAGOG SLATES.

The term Montpelier slate was submitted to the Committee on Geologic Formation Names at Washington, D. C., in 1906 for the

PLATE LVIII.

Granite Quarry, Derby.

long belt of the Lower Trenton slates flanking the Waits River limestone on the west and marking in Montpelier the last and therefore youngest terrane in the eastern part of the state. This name, I regret to state, was preoccupied and the committee therefore adopted the alternate term Memphremagog Slate, as proposed by the writer. The change is not inappropriate, however much the author might wish that one terrane typically represented within the capital of the state might bear that name.

True it is that the belt passing through Montpelier is lost in the neighborhood of Hardwick and Wolcott. Yet from lithological similarity and stratigraphical position, the typical areas about Lake Memphremagog belong to the extension of the same narrow belt.

The author seeking to give such names to the geologic formations of Vermont as will become permanent in geological literature has accepted the alternate, viz., Memphremagog Slate.

From the earlier reports of others upon the geology of Vermont, one is led to conclude that there is only one belt of slate traversing the area mapped in this report. The facts remain, however, that the Memphremagog slates now represent three long, narrow and parallel belts of slate extending from Lake Memphremagog southwesterly through Newport and Coventry. The strike of these slates varies from N. 30° East to N. 40° East and the dip is invariably to the west from 75° to 80°.

The first of these lies to the west of Barton River and is best seen along the heights of land between Barton Landing and Coventry. Here the black, carbonaceous slate becomes shaley and unsuitable for roofing material. Occasionally it is pyritiferous. It represents the finely triturated clays in the Ordovician seas which by metamorphism have become transformed into a non-fossiliferous slate and shale. This belt can be traced continuously through Coventry to Lake Memphremagog. It is flanked both upon the east and the west by the Waits River limestone.

The second belt consists of a black clay slate occasionally pyritiferous, yet with perfect cleavage. It is in texture more closely related to the Montpelier and Northfield slates, as they have been known commercially than the more easterly belt. The slate is uniform in color, easily worked and well suited for roofing purposes, blackboards, sinks, stationary washtubs, etc. It has been worked somewhat for road material, foundations for buildings, and is said to have been used for roofing purposes. The author has split this stone with hammer and chisel into slabs three-sixteenths of an inch in thickness.

Excellent opportunity is afforded for opening quarries about two miles south of Newport on the road to Coventry, where steep cliffs rise from fifty to seventy-five feet above the highway. This belt extends the entire distance from Coventry through Newport to Lake Memphremagog. It forms the range of hills just to the west of Black River. The river, however, has been cut in Waits River limestone and not in the slate. The highway follows the line of the strike on the eastern border of the state. It is therefore the easiest member to trace within the series. Even in the highly mantled drift area south of the lake occasional patches of the slate can be seen. In Newport village, on the road leading to Troy, it appears again. It crops out on the lake shore but passes under Lake Memphremagog to reappear again north of the International boundary. This belt, like the first, is flanked both upon the east and the west by the limestones. This belt must therefore from stratigraphical position be younger than the first belt of slate and still younger than the intervening limestone.

The third parallel belt of slate is separated from the second by the Coventry phase of the Waits River limestone. It stretches from Coventry northward to Lake Memphremagog, where, like the two preceding belts, it passes under the lake.

It is a black, carbonaceous, highly fissile slate. A typical representation can be found near the Town Farm in Coventry, but the best area for inspection can be seen along the Burlington road leading from Newport to Troy, as it passes through the northern part of Coventry. Here for a mile or more the road is parallel with the strike of the slate and unlike the Black River road it is located upon the slate. Near the small glacial mounds in the northwest corner of Coventry, there is a most excellent opportunity to quarry this slate. Thus far capitalists have not sought to develop this property, yet the slate here is well suited for all the ordinary uses. It can be split with hammer and chisel into as fine a roofing slate as any other slate within our borders. It trims also as readily and can be perforated for nailing without fracture. Several samples have been trimmed by the author into squares suitable for roofing material or exhibition purposes. It seems strange that this material lying so near the Boston & Maine and the Canadian Pacific railroads should have gone so long unnoticed.

Stratigraphically this is the youngest member of the Lower Trenton series in eastern Vermont. It is flanked on the east by the Coventry phase of the Waits River limestone and on the west by the Pre-Cambrian schists of the Reports of Prof. C. H. Hitchcock, which here have been termed Cambro-Ordovician.

If this logical interpretation be not true then the Coventry limestone lies in a bed of clay slate. Lithologically this is the finest of the three slates, the blackest and therefore the most carbonaceous. The history then of the Memphremagog slates may be interpreted as representing: First, a bed of finely triturated clays in the shallow, quiet waters of the Ordovician sea; second, a subsiding sea in which in the deeper waters the intervening limestone was formed; third, near the shore in comparatively still water the second belt of the finest muds and silts was laid down; fourth, a deepening sea again in which the Coventry limestone was formed; fifth, a shallowing of the sea when the waters of the Ordovician sea received their last contribution of sediments from the contiguous land areas now approaching base level. The sea now retreated at the close of the Ordovician and oceanic connection, with the Gulf of St. Lawrence closed.

F.

ACID IRRUPTIVES.

The term acid irruptives in this discussion is used to designate a series of intrusive rocks which are light in color, light in specific gravity, high in the point of fusion and holocrystalline.

In these respects they bear a striking contrast with the basic irruptives, which will be discussed later in this report.

a.

GRANITES.

The granites involved in the area of this report comprise a series of holocrystalline rocks whose essential constituents are quartz and the potash feldspar orthoclase, K_2O, Al_2O_3, $6SiO_2$, and whose accessory minerals are mica, or hornblende, or both mica and hornblende. No town in northern Vermont lying in the belt of the Waits River limestone is without this irruptive. These masses of igneous rocks are not always well suited for structural purposes near the surface, but usually, if not always, when below the sap rock and a short distance away from the limestones and slates which they have penetrated, they are free from iron and with good rift and grain. Distance from the railroad keeps some of these areas from being worked.

The most important locality in the vicinity of Newport lies some three or four miles from the town bearing this name, in the township of Derby, Vermont. This quarry site was opened about thirty-three years ago and for more than a quarter of a century the stone met only a local demand. In more recent years the beauty and permanency of this granite became generally known. The Newport Granite Company was organized under the presidency of Mr. A. A. Flint and with offices at Albany, N. Y. This company placed a most excellent product in large quantities upon the American market. Within the last two years Mr. George Farquharson, the former quarry manager, has leased the property and continues a flourishing industry, which now, with more machinery and more quarrymen, can put out $100,000 worth of stone each year.

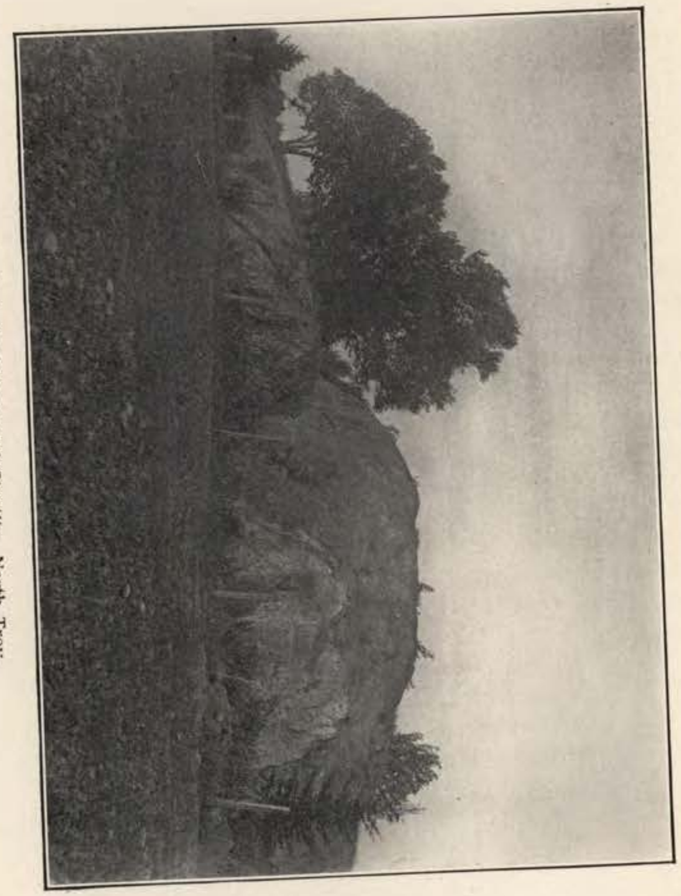
This granite is easily worked, is well suited for ornamentation but finds its greatest demand in structural purposes. No stone building can possess much greater beauty than one constructed from this material. It is mainly a biotite granite and the uniform arrangement of the black scales of mica with the white quartz and feldspar makes the stone "a thing of beauty."

Plate LVIII represents a portion of this quarry. Specimen No. 264 of the collection at Montpelier is a typical representative of this stone.

It is not within the province of this report of progress to describe all the granite areas of Derby, for the entire township has not yet been traversed. However, in the northern part of the township another large area appears along the eastern shore of Lake Memphremagog, stretching both north and south of the International boundary. These areas are not unlike the well-known field just north of the line at Graniteville, Province of Quebec.

Another area in Derby comprises a granite of much finer texture and darker hue, near the road leading from Newport to Barton Landing. The statement was made to the author many times that there was no granite in Coventry. True it is that in this township none has been worked save for underpinning or bridge construction, yet the author has discovered no less than half a dozen areas where this stone possesses good rift and grain. It is scarcely ex-

PLATE LIX.



Contact of Diabase and Steatite, North Troy.

ceeded in this respect by the well-known granites of the state. Some of these irruptives at least should find a ready market. They lie in the main along the crest of the eastern range of hills in Coventry and cut both the Waits River limestones and the Memphremagog slates. The mapable areas are represented in Plate LIV—the map of Newport, Troy and Coventry.

These areas cutting the Lower Trenton limestones and slates are all irruptives introduced near the close of the Devonian. That the granites to the north and west of the Devonian irruptives is older is proven by the fact that in the Irasburgh conglomerate, ten miles south of Newport, is found a few granite boulders from two to six inches in diameter. These must have been broken up along the shore by the rough waters of the Ordovician sea in order to have entered into the composition of this Lower Trenton conglomerate. The difference in both the color and texture of these earlier irruptives is very apparent, both in the field and in hand specimens.

In Newport Devonian granites are not known to exist in situ. There are, however, scattered over the township large boulders of granite with remarkable beauty, both light and dark varieties, but must be regarded as erratics from the Devonian areas in Canada. Specimens 299 and 300 were collected about one mile northeast of Newport Center on land owned by U. A. Harris of that village. These are representative of both the light and dark varieties.

On the farm of Augustus Lane, between the village of Newport and the center of the township, a granite quarry has been opened. This after a series of years has been abandoned. The joint planes in this are more numerous than in the Devonian granites to the east.

The rift and grain are not so perfect, the color not so uniform, and the stone not so easily worked as in Derby. However, it could be used for structural purposes. That it belongs to an earlier period of intrusives is apparent from its structural relations.

b.

GNEISS AND GNEISSOID GRANITE.

This comprises the only large single belt of acid irruptives within the area covered by this report. It first appears a little to the south of the International boundary, close upon the border of Lake Memphremagog and stretches across both Newport and Coventry.

It reaches a maximum width of about two miles. In its central portion it would normally be catalogued as a granite. It is in this central belt that the quarries of Augustus Lane hitherto noted are located. To the north it assumes a peculiar aspect by the introduction of a blue accessory mineral sodalite, and may therefore be called a sodalite granite. There are all shades and gradations between these granites in which no parallelism of the secondary minerals is apparent, and granitoid gneiss, to perfect gneiss in which the parallism of the mica is always clearly seen. The borders of the belt are highly porphyritic, the phenocrysts of the feldspar orthoclase are often two inches in their longer diameter and frequently twinned. The porphyritic phase lies both to the east and the west of the more granitoid gneisses. On the shore of the lake, south of the metal lighthouse, this porphyritic phase is very well defined, and especially so one mile west of the lake north of the northern road leading from the lake to Newport Center. Again in the northern part of Coventry large phenocrysts of orthoclase appear in the gneiss. This porphyritic nature gradually dies out on the western flank and graduates by almost insensible gradations into gneiss very fine grained. This latter phase may be observed on the western slope of Coburn Hill in Newport.

Were it not for the fact that a fine grained phyllite, although highly drift-covered, is occasionally found flanking this belt both upon the east and the west, one might be led to conclude that here we have Pre-Cambrian feldspathic schists metamorphosed into a gneiss and not the more granitic areas representing the more highly metamorphosed gneiss.

The author has been led to conclude, however, that the original intrusive was a Pre-Devonian granite, that through regional metamorphism it has passed into a granitoid gneiss, and into a gneiss in whose marginal phase the granitoid character has been obliterated. Furthermore, that it was this belt of early irruptives, whose age is not definitely known, save that it is Pre-Devonian, that furnished the granitic element in the local Irasburgh conglomerate. It is worthy of note that these acid irruptives do not appear again east of the major axis of the Green Mountains.

G.

BASIC IRRUPTIVES.

The term as here utilized includes a series of intrusives that are basic in their nature and therefore more easily fusible than the acid

holocrystalline rocks just described. As these basic members are generally dark in color, high in specific gravity, often micro-crystalline, they form a striking contrast with the granites and gneisses.

a.

DIABASE.

The term as here used applies to a series of heavy basic intrusives consisting essentially of plagioclase, augite and magnetite. Olivine may or may not be present. In this discussion there may be included some highly metamorphic rocks, that without microscopic slides it may be impossible to say with definiteness whether they represent metamorphosed sediments and therefore the metadiabase of Dana, or sheared diabases. The diabases occurring as narrow dikes cutting the Lower Trenton limestones and slates nowhere appear as mapable areas in this report, but in the Cambro-Ordovician Series there are many mapable areas. The largest of these comprises the main mass of Bear Mountain across which the International boundary runs. To the south of the mountain in both Newport and Troy there are numerous patches cutting these older schists.

In Newport especially the outcrops appear beautifully rounded and closely resembling the roche mountainee of glaciated highlands. Along the western shore of Lake Memphremagog the diabase is of the camptonite order. The rock here appears as a dark basaltic rock, with a few large shining crystals of hornblende, closely resembling those discovered in the Pemigewassett Valley in New Hampshire by Dr. Oliver Payson Hubbard. Another extensive area of the diabase is found in the Black Hills in the southern part of Newport. The mountains were not named from the black diabasic masses, as one might readily suppose, but from the blackened appearance of the oxidized sulfids of iron in the crystalline schists that form the main mass of the mountains.

It becomes impossible to outline all the areas, neither have all outcrops of this basic igneous rock been discovered, through lack of time, but the large and more important areas are marked upon the map and through large dikes were also traversed in the geological section.

The age of the intrusives has hitherto been considered a little uncertain. In my field work in June, 1908, the relation to all the other igneous rocks was definitely settled. They cut all the different series of the crystalline schists and the limestones, also all other intrusives, from the basic peridotites to the acid granites.

About one mile east of North Troy is found the absolute proof of this fact. The diabase has cut the serpentinous and steatitic masses, giving a clear zone of contact metamorphism on the western side of the exposure, and brought up also an inclusion of steatite on the eastern side. Plate LIX represents this phenomena. The dark area forming the main mass is the diabase and the light area the steatite. This is an indisputable fact, that it cuts the oldest basic intrusive. As dikes of considerable proportion, it appears cutting both upon the east and the west the broad belt of gneiss and gneissoid granite in both Newport and Coventry. It therefore is younger than the oldest acid intrusive. Still further to the east it is found cutting the Devonian granites. Hence it is younger than the most acid intrusive.

The author is therefore able to state that these diabasic rocks are the youngest intrusive of the entire field. I do not, however, mean to imply that they are Post-Mesozoic, like the palisades of the Hudson, but rather that they represent the latest work of intrusion at the close of the great Devonian Revolution.

b.

BASALTS.

The term as here used signifies a series of dark basaltic rocks, microcrystalline in texture, whose true nature can only be determined by the careful study of microscopic slides yet to be prepared. Perhaps these should be included in the list of diabases, but their dark color and high specific gravity has led the author to catalogue them as basalt. Microdiabase might have been a better term. A good illustration of their aphanitic character is seen in the western part of Newport, one half mile north of the Burlington road leading to Troy.

c.

DIORITES.

These represent a series of granitoid rocks consisting essentially of plagioclase and hornblende. Several good illustrations of this type of basic igneous rocks are found in the western part of the township of Newport, near the Troy line, and again to the west of Newport Center. Some of these closely resemble the gabbro-diorites of Essex County. They are coeval with the diabasic rocks. Many samples of all these types of basic intrusives are included in the list of specimens in the museum at Montpelier, Vermont, and material reserved for microscopic study.

d.

PERIDOTITES.

The term peridotite, as here applied, embraces a series of rocks sometimes granitoid in texture, occasionally porphyritic, but always dark, heavy and basic. This belt reaches a maximum width of about three miles in Troy and Jay. It extends also into Lowell and Eden, both of which lie outside the area of this report. In Lowell and Eden it is best developed and here it gives rise to asbestos, variety chrysotile, which has been worked to some commercial advantage.

These peridotites have cut both the sericites and the pyritiferous mica schists. They lie mostly in the sericites. Their original nature is a little difficult to ascertain because the rock is now so highly metamorphosed. In their northern extension, which has been traced by the Canadian Survey under the direction of Prof. John A. Dresser 150 miles to the northeast and studied by the author in the Black Lake and Thetford mines district, Megantic County, Province of Quebec, they now carry well-defined crystals of bronzite. It is in this belt that the chromite and magnetite and asbestos mines of Canada, which have become so important from a commercial standpoint, are located.

These economic products occur also in considerable quantity in Vermont. One of the best magnetite beds is found in Troy about two miles northeast of the village bearing that name. Three veins of the ore was worked some sixty or seventy-five years ago and the resulting iron was used only locally on account of the great distance from the railroad. A portion of the ore was worked in a foundry situated on the banks of the Missisquoi River, while a part was shipped to St. Johnsbury, some fifty miles distant. The freedom from sulphur in this ore makes the resulting iron especially well suited for carwheels, axles, curved rails, etc., and in fact for all purposes where an extremely tough steel would be desirable. That the finished product is easily fashioned into any form to serve the purpose of the manufacturer is shown in the products of the crude works of more than half a century ago.

The chromite is well represented in the serpentine about two miles from North Troy, on the line between Troy and Jay. Here samples of chrome ore were found more than one foot in diameter and of high degree of purity. This is well illustrated by sample 332 of the collection at Montpelier.

The chromite has also been worked about one mile southeast of Troy, on property controlled by Judge David. There are two reasons why this section is not actively exploited for both the magnetite and chromite which it contains. The first is the distance from railway, which could be obviated by the southern extension of the Mount Orford Railroad. The second is the great distance of the ores from the extensive beds of bituminous coal, which are so important in the metallurgy of iron.

The metamorphism of the peridotite to serpentine has given rise to numerous beds of asbestos, the fibrous, silky variety, chrysotile with fibers set transverse to the planes of fracture, but occasionally found parallel with those planes.

The continued development of the asbestos mines in Lowell and Eden, described in the annual report of the State Geologist of 1903 and 1904 by Prof. V. F. Marsters, may lead to active and profitable exploitation for asbestos in this area. In this belt, associated with serpentine, there is also much steatite, the massive form of talc, a hydrous silicate of magnesium, H_2O, $3MgO$, $4SiO_2$. The steatite often carries many crystals of breunerite commonly called brown spar. They become brown upon exposure to the atmosphere through the oxidation of the iron. The steatites are the modern representatives of the more highly magnesian minerals of the original peridotite belt.

Bordering the peridotite belt on the west and not far from the village of Troy, there are several outcrops of what at first sight might easily be taken for dolomite. Upon closer examination it does not look like a clastic rock. Its qualitative analysis, save in a few crystals, reveals only a trace of calcium carbonate. The insoluble residue of silica shows no trace of rounded grains of sand as one might expect from a siliceous magnesite or magnesian sandstone. Some prominent exposures are locally called "the red rocks," from the oxidation of the iron which the rocks contain. It appears to be an alteration product of some highly magnesian phase of the peridotite. Its high specific gravity and striking peculiarities make it an object well worthy of future study.

The solution of the exact geological age of these peridotites appears to be no easy problem. That they are Pre-Devonian is proven by the fact that they are highly metamorphosed before they are penetrated by the unquestioned diabases—the last basic intrusive of the Devonian revolution.

In the summer of 1907, while engaged in the study of the best developed area of the northern extension of this belt in the neighborhood of Black Lake, Megantic County, Province of Quebec, with Prof. John A. Dresser of the Canadian Survey, we arrived conjointly at the following conclusions:

First, reasons for the appearance of granites in the peridotite belt.

Reasons for being intrusive:

1. Dike-like forms with distinct hanging walls.
2. Lenticular masses dislocated by distinct thrust faults.
3. Abundant shearing and faulting of the peridotite.
4. Presence of stibnite in the aplite—the most acid material of the peridotite belt.

Reasons for being contemporaneous:

1. Uniform granularity of the granite.
2. Irregular masses entirely disconnected within the peridotite.
3. Totally fused contacts free from sulfids.
4. Absence of metamorphism in the contact zone.
5. Presence of spheroidal masses of chromite within the granite.
6. Margins of granite impregnated with chromite.
7. Increasing abundance of granite toward the center of peridotite belt.
8. The zonal distribution of the irregular masses of granite.
9. General aplitic character of the granite.
10. Bisilicates when present are hornblende and not mica.

Second, Conclusions for the solidification of the main peridotite belt.

The segregation of minerals followed the law of decreasing basicity.

1. Chromite and magnetite.
2. Peridotite with pyroxene phases.
3. Granites.
4. Quartz.

H.

CLAYS.

As I stated in my report of 1905–'06, scarcely a town exists in the northeastern part of Vermont that is without its brick houses and old brickyards. The statement holds equally true for Newport, Troy and Coventry. While there are no manufacturing industries along this line at the present time, there are several good beds of Pleistocene clays within these townships well situated for the manufacture of brick. One of the best of these is situated on the west shore of Lake Memphremagog and is overlaid by a few feet of Memphremagog sands. The clays here are of exceptional purity and good plasticity.

I.

ECONOMICS.

The economic products of the area involved may here fittingly receive a brief summary, although their presence has been intimated from time to time in the general discussion.

1. The acid intrusive granites that have become so potent a factor in the commercial development of Vermont. With the true granites that find their best representatives in Derby there should be included the gneisses and gneissoid granite of Newport and Coventry.

2. The basic irruptives, diabases, diorites and gabbros that can be utilized as road material in the manufacture of permanent roads. The supply of this available material is inexhaustible. Such sandy highways as one encounters in the Black River valley may be made into a boulevard through the proper use of this material.

3. The slates of Coventry in this portion, free from pyrite, are fully equal to the best roofing and blackboard slates within the state. One has only to trim out with hammer and chisel either square or rectangular slabs in the westernmost of these three belts of Memphremagog slates to be convinced of this fact.

4. The limestone in Coventry in its purer phases can be easily manufactured into lime, while at Barton Landing it is well suited for minor building purposes.

5. The sericite schists of Troy sometimes possess the perfect cleavage of slate and in their more massive phases can be utilized for underpinning and bridge construction.

6. The chromite and magnetite ore of Troy, Jay and Westfield

ought not to go long unexploited and unworked. If they could have been worked with some degree of profit, as they seem to have been when there was no railroad nearer than Concord, N. H., they certainly should yield a fair profit on investments with the Canadian Pacific Railroad at North Troy and the Boston and Maine at Newport.

7. The asbestos of the serpentine belt now worked in Eden and Lowell, and so extensively worked in Canada, may be discovered in paying quantities in this area, where several patches of the fine short fibres appear upon the surface of the outcrop.

8. Good samples of bog manganese ore were collected in the densely wooded areas in the southern part of Newport, the extent of which is unknown.

9. Fine samples of copper ore from the neighborhood of Coburn Hill in Newport have been shown the author, and samples also of low grade copper, rich in their sulphuric acid content, have been collected in the northern part of Newport, where a shaft has been sunk some thirty or forty feet without striking a well-defined vein of these sulphides of iron and copper. Should such a vein be ultimately found, it would find a ready market in the manufacture of paper by the sulphite process.

10. Gold. A continuous quest for gold in this field of metamorphics both on the part of farmers and speculators has led to the report of numerous shafts sunk, or quartz veins opened, for the extraction of the yellow metal.

Gold does occur in minute quantities in many of these quartz veins, but none of them seem rich enough or extensive enough to forecast the development of a gold mining industry in Vermont.

Many samples were collected and assayed by the author to satisfy the desire of the people most directly concerned. One sample from the northern part of Newport gave a gold value of $6.82 per ton of ore. One from the Black Hills in Newport gave $16.78 per ton. It was a carefully selected sample and could in no way represent the value of a well-defined vein. One can be directed to this property by Carl Cole, North Troy, Vt., R. F. D. No. 1.

In the northeast corner of Irasburgh, on land owned by A. H. Miles, Barton Landing, Vt., there are numerous auriferous quartz veins. One gave $3.61 per ton of ore. The gold in them all is widely disseminated and seldom if ever will be found in paying quantities.

J.

PALEONTOLOGY.

Since submitting my report in 1906, in which the paleontological evidence was discussed for northeastern Vermont, the author has discovered two small areas in the Waits River limestone, in which crushed graptolites seem to abound. The first of these was found in June, 1907, in the township of Coventry near the Hill road leading from New York to Barton Landing and about 4 miles south of Newport. Many samples for further study were collected, showing these evidences of crushed graptolites lying parallel with the planes of bedding in limestone and apparently coinciding with the planes of foliation of the rock. One sample was submitted to Prof. John A. Dresser of McGill University, Montreal, and in charge of the Canadian survey of the Eastern township in Quebec, who immediately catalogued the evidences of Aryonic remains as crushed graptolites; and later in a personal letter to the undersigned said, "Your graptolites will no doubt prove genuine." Later these specimens of limestone were compared with samples of slate personally obtained at Castle Brook, Magog, Quebec, the classic area for graptolites, and the appearance of the crushed forms in the two rocks were very closely identical. This classic area lies about 40 miles to the north of Coventry. The forms in Canada are well preserved and amongst them I have identified fifteen different species of Lower Trenton Age and catalogued them in my report contained in the annual report of the state geologist, 1901–1902.

The second small area was discovered in Brownington in June, 1908, several miles to the east of the area in Coventry. Here, too, the crushed forms are in the Waits River limestone and their appearance is even more abundant than in Coventry. Their facial aspect is exactly identical with those of the first discovery. Several samples were submitted to Mr. Perkins, a geologist and civil engineer of Canadian training, who immediately considered the discovery of crushed graptolites important and a true diagnostic feature of age. Samples from each locality have been placed in the collection of 333 specimens already referred to and sent to the museum at Montpelier, where they may be seen at any time. The forms are too badly mutilated for the identification of the species, but their abundance, especially in the Brownington field, leads me to believe that other areas will yet be found, in some of which the graptolites will be far better preserved.

Diligent search for fossils in Memphremagog slates and shales south of the international boundary has not yet been rewarded with the first evidence of the discovery of organic matter suggestive of a graptolite. To be sure these terranes are largely drift covered, often to a great depth, but in the patches of slate exposed here and there some new light may yet be thrown upon the problem.

The discovery, if it proves a genuine field, has a peculiar significance. In the Canadian territory the true diagnostic feature lies in the slates and shales and not in the limestones with which these rocks are so closely associated. These are both catalogued from stratigraphical relations of the limestones to the slates, Lower Trenton, yet only a few traces of the forms have been found in the limestones. The accuracy of the Canadian map is testified to by the presence of these crushed graptolites in the limestones in Vermont without their discovery within our borders in the Memphremagog slates and shales.

Thus in our work we are able to aid each other, for the geological formations stretch continuously across Vermont in a northeasterly direction into the Province of Quebec. The upper portion of the Waits River limestone and all of the Memphremagog slates and shales remain with concurring proof where first the author placed them in 1895, as Ordovician and more specifically Lower Trenton. The third belt of slate would therefore appear to be the youngest of all these terranes and ceased to form with the great continental up-lift at the close of the Ordovician.

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