REPORT

OF THE

STATE GEOLOGIST

ON THE

MINERAL INDUSTRIES AND GEOLOGY

OF

VERMONT

1923-1924

FOURTEENTH OF THIS SERIES

GEORGE H. PERKINS

State Geologist and Professor of Geology
University of Vermont

BURLINGTON, VT.:
FREE PRESS PRINTING CO.
1924.

STAFF OF THE VERMONT GEOLOGICAL SURVEY, 1923-1924.

CONTENTS.

LIST OF PLATES.

FIGURES IN THE TEXT.

STATE OF VERMONT.

OFFICE OF STATE GEOLOGIST.

BURLINGTON, January 6, 1925.

To His Excellency, Redfield Proctor, Governor:

Sir:—In compliance with Act 405 of the General Laws of this State, I herewith present my Fourteenth Report on the Geology of Vermont.

This Report, according to law, covers the Biennial Period 1923-1924.

The portions of the area of Vermont studied are indicated in the Introduction which follows.

During the Biennial Period the surveying and mapping, begun several years ago, by the United States Geological Survey in cooperation with this State has been successfully carried forward until now more than two-thirds of the total area is completed.

The War Department also is greatly advancing this work by surveying a series of Quadrangles across the northern border. The maps thus produced are uniform with those hitherto made.

Respectfully submitted.

GEORGE H. PERKINS,
State Geologist.

INTRODUCTION.

As now a very considerable portion of Vermont has been mapped by the U. S. Topographical Survey, about two-thirds, and as from these maps the altitude, of any mountain, hill, town, etc., which is within the limit of these maps, *i. e.*, its exact height above sea level can be found, the Geologist has in this Fourteenth Report given as the opening article a list of all such elevations as are known.

Of course, when the whole State is mapped, a complete list can be made, but it will be several years before this can be done. In the second article the Geologist gives as supplementary to what he has published in former Reports some further account of the Geology of Grand Isle County. Following this is an interesting study of an Ancient Coral Reef on Isle La Motte by Dr. P. E. Raymond of Harvard University.

A very important article reprinted, with some changes, from the *Am. Jour. of Science,* is a report of study which has been carried on for several years by Mr. Arthur Keith of the U. S. Geol. Survey, of the very perplexing relations and structure of the Cambrian Beds of Western Vermont. Very properly following this is an extended account of Some New Trilobites found by Mr. Keith in course of his investigation, by Dr. Raymond. Dr. C. E. Richardson, of Syracuse University, continues his long study of the rocks of eastern Vermont, this paper taking up those of Bethel. Two papers in preceding Reports by Dr. C. E. Gordon of Massachusetts Agricultural College, on the Geology of Western Vermont, are here followed by a third in which this study is further advanced.

A study of the Ordovician beds of the Champlain Valley, by Mr. E. J. Foyles of the Am. Museum of Natural History, New York City, which has been carried on for several years, is continued in his article in this Report, by which he especially carries his work to Bridport, Shoreham and Fort Cassin.

Professor G. D. Hubbard of Oberlin College, who during several seasons has conducted geological investigations, with a class of geological students in Bennington and Windham Counties, has furnished an extended report of some of the work done.

This work will be found interesting and valuable to the geographer as well as to the geologist.

The usual summary of the Mineral Resources of the State concludes the volume.

The Geologist is confident that much of interest, especially of course to geologists, will be found in some of the above articles.

In all of them will be found material regarding the geology of the State that is new and that must aid in no small measure to a better understanding of some of the many difficult questions which are presented by the rocks of Vermont.

A DICTIONARY OF ALTITUDES IN VERMONT AS ASCERTAINED BY THE ENGINEERS OF THE UNITED STATES TOPOGRAPHIC SURVEY.

As the Ninth Report of the Vermont State Geologist contains a somewhat detailed account of the work of the United States Topographic Survey and its results as far as this State is concerned, it should not be necessary to repeat here more than a brief statement of this work, nor should it be needed that an extended statement of the great value of the maps which are made by the Survey be given. No one who has examined and used these maps can fail to understand how far they excel any previous maps of Vermont or any others that can be produced.

As is stated in the Report referred to above, the work of mapping different areas in Vermont began when Survey, working eastward in New York State, crossed Lake Champlain and included in the eastern tier of Quadrangles some part of western Vermont.

From the first, it has been the rule of the National Survey to issue the maps in "Quadrangles," each of these covering one-fourth of a degree, though other and larger sizes are sometimes made when some special demand appears to require it. A map including a fourth of a degree is usually sixteen and a half inches wide and twenty inches long—the scale being 1-62,500.

The area covered by each map is somewhat variable, depending mainly upon the longitude, but is not far from 220 square miles in the Vermont maps.

As maps made on the above scale, 1-62,500, which is that of the Vermont maps, are, for all common purposes, one inch to a mile, it is very easy to measure the distance between two points on the road or elsewhere. Of course, for engineering purposes more exact figures would usually be needed and could be readily found. So too when desired, all elevations may be read off from the brown contour lines of the map, the lighter lines being always twenty feet apart and the heavy lines one hundred feet. All this and a great deal more is explained on the back of each map. It may be useful if a few quotations from these explanations are given here.

"Relief is shown by contour lines in brown. A contour line represents an imaginary line on the ground, every part of which is at the same altitude above sea-level. Such a line could be drawn at any altitude, but in practice only the contours at certain regular intervals of altitude are shown.

"The contour interval, or the vertical distance between one contour and the next, is stated at the bottom of each map.

"Lettering and the works of man are shown in black. Boundaries are shown by continuous or broken lines. Metalled roads are shown by double lines. Other public roads are shown by fine double lines, private and poor roads by dashed double lines, trails by dashed single lines.

"Each quadrangle is designated by the name of a city, town or prominent natural feature within it. Over 3,000 quadrangles in the United States have been surveyed."

To the present time (1924), forty-five maps of quadrangles, each covering some area in Vermont, have been made. Of these, twenty-five are wholly in Vermont, eight partly in Vermont and partly in New York, three, mostly in Massachusetts, but taking in a small strip of southern Vermont, two in Vermont and New Hampshire.

Application to the Director, U. S. Geological Survey, Washington, D. C., will bring a key map of Vermont and New Hampshire, whereby one can see just where in each State quadrangles are located, as may be also seen by consulting the list on following pages.

A few bookstores in this State keep a stock of these maps on hand or they can be obtained by applying to the Director, U. S. G. S., as above. They are sold for ten cents each, or when fifty, alike or different are ordered, at six cents each.

For some years this State made no appropriation towards the expense of the topographic maps, the few that were made, being financed either by the Federal Survey or by the adjoining states, but in 1913 and for each year since, the Legislatures have set aside, at first two and, later, three thousand dollars in cooperation with the Federal Survey. That is, for the expense of field work, Vermont contributes a certain sum and the Federal Survey adds an equal amount. This being done, the Government finances the drawing, printing, etc., and sells the maps at about cost.

The above described cooperative arrangement results in a series of maps, ultimately covering the whole area, such as the State alone could not afford. In this way Vermont gets not only a far finer set of maps of the area of the State, but maps the use of which may here, as it has done in other states, save in laying out roads, building reservoirs, locating canals, or dams and many other ways, much larger sums that have been expended. Thus appropriations for this work are sure to prove in the long run a very profitable investment for the State. Many states have and and are appropriating far greater sums for this purpose.

In examining the maps one at once notices that for obvious reasons the quadrangles or sheets do not and cannot be in any way guided by township lines. Since the quadrangles are of practically uniform size and the towns are by no means so and, also, for the most part, far from quadrangular, there can be no coincidence. Hence a township may be wholly included within one of the quadrangles, or it may be partly in one and partly in a second, or, less commonly, it may even be found in three. Because of this it is not always easy to know which of the sheets to order when one needs a map of a given town and the following table is given from which it may readily be found in what quadrangle, or quadrangles, the town is included. It will be seen that to secure the map of an entire township it may be necessary to order two or three sheets, though often only one is needed. Such a table is given in the Ninth Report of this Series, but as this was published in 1914, since which time many additional towns have been surveyed, the list is now nearly doubled.

The finished quadrangles are taken up in geographical order, beginning at the north border of the State and proceeding south.

Before presenting a list of towns and giving the quadrangles in which they are located it may be a convenience to some if a list of the quadrangles surveyed is given in less detailed form.

About three-fourths of the State is now surveyed and several more quadrangles will be finished this season, 1924. As has been seen, each map, or sheet, gives one quadrangle and covers "from 212-220 square miles."

In the following list the order is from the northeast corner of Vermont, crossing to the eastern border in one tier of quadrangles and then moving south to the next tier, again commencing on the west and so on, covering the whole State as far as surveys have been made. As the western tier of quadrangles was made not by Vermont, but by New York, and are all of them occupied by areas in each of the two states, these have New York names. Beginning with the northeastern part of Vermont, we find:

THE ROUSES POINT SHEET OR MAP.

About half of this sheet is covered by Vermont territory as the map crosses Lake Champlain and extends nearly to the eastern shore of the lake. Reaching to the Canadian boundary on the north, it includes most of the large peninsula of Alburg, the whole of Isle La Motte and North Hero and the northern end of Grand Isle.

THE ST. ALBANS SHEET.

This map covers most, though not all of Franklin County, of which St. Albans is chief, thus giving the name to the map.

THE ENOSBURG FALLS SHEET.

This and the following three quadrangles were surveyed and the maps made by request of the War Department during last season (1923), and with the Island Pond and Averill quadrangles complete the northern border of the State.

The Enosburg Falls map includes an area wholly in Franklin County, going east through much of Berkshire, Enosburg and Bakersfield.

JAY PEAK SHEET.

This sheet covers the eastern part of Franklin County and a few miles of the western part of Orleans County. Here are the eastern parts of Berkshire, Enosburg and Bakersfield, and the northern parts of Belvidere and Eden, the whole of Montgomery and Richford and a few miles of the western parts of Jay, Fairfield and Lowell.

IRASBURG SHEET.

All of this quadrangle is in Orleans County, the towns being the western part of Jay, Westfield and Lowell, a triangular bit of the northern part of Albany, the whole of Troy, a large portion of Newport and Irasburg, and the eastern part of Coventry.

LAKE MEMPHREMAGOG SHEET.

This map includes Newport town, the southern end of Lake Memphremagog, Newport City, much of Coventry, a considerable area in eastern Irasburg, most of Barton, a considerable part of Westmore, including the northern part of Lake Willoughby, the whole of Brownington and Derby, the west part of Holland, the west part of Morgan and most of Charleston.

As previously stated, the two additional quadrangles needed to complete the northern boundary of Vermont have not yet been finished, but probably will be in the near future.

PLATTSBURG SHEET.

Returning to the eastern border of Vermont we find that the Plattsburg sheet covers a strip of Lake Champlain and includes the western point of Colchester as well as nearly the whole of Grand Isle, in Vermont.

MILTON SHEET.

Nearly all of this map takes in the mainland of Vermont, altho on the west it includes quite an area of Lake Champlain. The map covers the whole of Milton and Georgia, southwestern Fairfax, west part of Westford, most of Colchester, a considerable part of Essex, and a small bit of Burlington.

The Mount Mansfield Sheet will probably be completed this season, but is not yet ready for distribution, as also the Randolph Sheet.

WILLSBORO SHEET.

More than half of this sheet is occupied by Lake Champlain, but it covers a considerable strip of eastern New York and western Vermont. It includes far more of the former State, but the shores of Shelburne and Charlotte and a little of northern Ferrisburg are seen on the Vermont side.

THE BURLINGTON SHEET.

On this map may be found nearly all of Burlington, Williston, Shelburne, Hinesburg and Charlotte, much of Richmond, a little of Essex, Jericho, Huntington and the north end of the Addison County towns, Starksboro, Monkton and Ferrisburg.

CAMELS HUMP SHEET.

This covers the eastern part of Jericho, Richmond, Huntington and a little of Starksboro. On the north is a considerable part of Underhill and less of Stowe. It covers the whole of Duxbury and Bolton and a large area in Waterbury. On the south a corner of Fayston and also of Moretown comes in.

MONTPELIER SHEET.

A large part of Stowe, Waterbury, all of Worcester and Middlesex, a considerable part of Moretown, Elmore and Montpelier town, with all of Montpelier City. A bit of Morristown on the north and Berlin on the south are also shown on this map.

WHITEFIELD SHEET.

From the Montpelier Sheet east to the Connecticut River the area has not yet been surveyed except a small region in the northwest corner of New Hampshire-Whitefield Sheet. This includes a very small part of the town of Guildhall and a large part of Lunenburg. The main portion of the map being in New Hampshire.

PORT HENRY SHEET.

As the name indicates, this is a New York map, but like the other New York maps of the eastern border, it includes a part of Lake Champlain and more or less of the western border of Vermont. In this particular sheet we find more of Vermont than of New York, as is also true of the Ticonderoga and Whitehall Sheets. The Port Henry Sheet covers nearly the whole of Ferrisburg and the entire area of Panton and Addison, together with a strip of the northern part of Bridport.

MIDDLEBURY SHEET.

Next east of the Port Henry Sheet comes Middlebury. Here we find the whole of Bristol and New Haven, most of Monkton and Weybridge, much of Starksboro, Ferrisburg, Middlebury and Ripton, a little of Cornwall and Lincoln.

LINCOLN MOUNTAIN SHEET.

This sheet is a map of mountain towns, as the contour lines show, and it includes the whole of Warren, much of Fayston, Granville and Waitsfield, a good bit of Lincoln, less of Ripton and Roxbury, and smaller portions of Starksboro, Northfield, Huntington and Moretown.

BARRE SHEET.

This sheet contains a large part of Moretown, Barre town, including Barre City, Northfield, Roxbury, Williamstown, nearly all of Berlin, most of Brookfield and small areas in Braintree and Chelsea.

Two quadrangles east of Barre have not yet been surveyed.

TICONDEROGA SHEET.

This New York sheet includes more of Vermont territory than of New York. Besides the southern twenty miles of Lake Champlain it takes in of Vermont the following towns: Bridport, Shoreham, Orwell, a large part of each and a small bit of the north part of Benson.

BRANDON SHEET.

This sheet contains the whole of Salisbury, Whiting, Leicester, Sudbury and Brandon, a large part of Cornwall, smaller areas in Middlebury, Ripton, Shoreham, Orwell, Pittsford, Chittenden and Goshen.

ROCHESTER SHEET.

This is another series of mountain towns, perhaps most so of any in the State. In this quadrangle are: The whole of Hancock, a large part of Rochester and Pittsfield, more or less of Ripton, Granville, Goshen, Chittenden and Braintree.

RANDOLPH SHEET.

This area is being surveyed this season (1924) and will probably be issued in 1925.

STRAFFORD SHEET.

This sheet includes all of Strafford, much of Chelsea, Vershire, Tunbridge, Sharon and Thetford, a considerable area in Norwich, a little of Fairlee, Corinth and Royalton.

Less than half a quadrangle between the Strafford and the Connecticut River is unsurveyed.

WHITEHALL SHEET.

This is the most southerly of the New York sheets that furnish information of Vermont localities. It also gives the southern portion of Lake Champlain. Most of Benson and all of West Haven, as well as a not large area in western Fair Haven, including the village.

CASTLETON SHEET.

Next east comes the Castleton Sheet, which includes all of Castleton, Proctor, West Rutland, most of Hubbardton, Pittsford, Poultney and Ira, a part of Clarendon, the eastern edge of Benson and Rutland, including Center Rutland.

RUTLAND SHEET.

This sheet covers the whole of Mendon, most of Chittenden, Rutland, Sherburne and Shrewsbury, a considerable part of Clarendon and less in Stockbridge, Pittsford and Plymouth.

WOODSTOCK SHEET.

Next east of the Rutland Sheet comes the Woodstock, which covers all of Bridgewater, most of Braintree, Woodstock and Plymouth, a part of Pomfret and Reading, less of Stockbridge, Sherburne and Hartland, the corner of West Windsor.

HANOVER SHEET.

Although a New Hampshire sheet, this includes more on the west of the Connecticut River than on the east, for it covers the whole of Hartford, much of Norwich and Hartland, Pomfret, the north part of West Windsor and Windsor, a little of Sharon and Woodstock.

FORT ANN SHEET.

This New York sheet includes but very little of Vermont. Commencing at the south, there is a strip scarcely more than half a mile wide in Rupert. This grows still narrower towards the north until in Wells it runs out. There is little use, so far as Vermont is concerned, in consulting this.

PAWLET SHEET.

This map does not contain the whole of any town, but there is nearly all of Tinmouth, Wells, Pawlet, Danby, Rupert and much of Dorset and Middletown, with a little of Wallingford, Ira and Clarendon.

WALLINGFORD SHEET.

In this map we find most of Wallingford, Mt. Holly, Weston, all of Mt. Tabor, a considerable part of Peru, a little of the edge of Landgrove, Clarendon, Shrewsbury, Ludlow, Andover, Danby, Dorset.

East of what is shown on this map to the Connecticut River, one quadrangle and about a third of another are not surveyed.

CAMBRIDGE SHEET.

Like the Fort Ann Sheet, this extends east only a very short distance in Vermont. It takes in a narrow strip of the western border of Shaftsbury, Arlington, Sandgate and Rupert. The rest, almost the entire sheet, shows areas in New York.

EQUINOX SHEET.

In this quadrangle is contained all of Manchester and Sunderland, nearly all of Sandgate and Arlington, the southern part of Rupert and Dorset, the northern part of Shaftsbury and Glastenbury.

LONDONDERRY SHEET.

Most of Londonderry, Winhall, Stratton, Jamaica, a large area in Wardsboro, and smaller bits of Dorset, Landgrove, Windham and Somerset are found here, also quite a territory in Peru.

One quadrangle and a narrow strip along the Connecticut remain thus far unsurveyed in this tier.

HOOSICK SHEET.

The most southern series of complete quadrangles in Vermont begins on the east with the New York-Hoosick Sheet which, however, includes only a narrow strip, nowhere much more than two miles wide and mostly less. This narrow area, so far as Vermont is concerned, takes in the extreme western part of three Vermont towns, Shaftsbury, Bennington and Pownal.

BENNINGTON SHEET.

This sheet includes nearly all of Shaftsbury, Glastonbury, Bennington, Pownal and Stamford, all of Woodford, a little of the west border of Somerset, Searsburg and Readsboro.

WILMINGTON SHEET.

This includes all of Wilmington, a large part of Somerset, Dover, Searsburg, Readsboro and Whitingham, a portion of Marlboro and Halifax and a bit of Newfane.

BRATTLEBORO SHEET.

This covers most of what is left of southern Vermont and all of the southeastern corner. All of Dummerston and Brattleboro, nearly the whole of Guilford, a considerable part of Newfane, Marlboro and Halifax, and a smaller part of Putney and Vernon are found on this map.

GREYLOCK SHEET.

Three of the Massachusetts sheets each extend north of the State line and thus cover a small part of the southern tier of Vermont towns, but none of these contains very much of use to one seeking information as to this State. The Greylock map shows a narrow strip of Pownal, Stamford and Readsboro.

HAWLEY SHEET.

This gives a little more of Vermont—the southern border of Readsboro, Whitingham and Halifax.

GREENFIELD SHEET.

With this map the rest of the southern border of Vermont is shown in a strip, perhaps a mile, or a little more, in width, of Halifax, Guilford and Vernon.

As has been already noticed, a number of our Vermont towns are not entirely on one map, but several will be required if one needs the whole township.

The above list gives the extent of the different quadrangles which have been completed in Vermont, but for some purposes, perhaps most, a somewhat different arrangement will be found more convenient and such a list or table is here given whereby the location in a given quadrangle or quadrangles may be very easily seen.

As lists similar to those given here are found in the Tenth Report, it may be thought superfluous to print the following lists in this Report, but during the seasons which have passed since the first list was published, large areas of the State have been surveyed and, hence, a much more complete list of the towns is now possible as has been stated.

A considerably larger list could be published but for the fact that there seems to be no way by which unnamed hills and mountains can be distinguished. The very mountainous character of some parts of Vermont is very forcibly shown by the fact that in the State there are now two hundred and ninety-seven (297) peaks which are two thousand feet or more in height that have never been named and, of course, for this reason cannot be listed. Probably as many more could be found between one and two thousand feet high so that the sum total of uncatalogable elevations is large, especially when it is remembered that the entire area of the State is less than ten thousand square miles. In some especially mountainous towns, like Chittenden or Goshen, there may be twenty or even thirty mountains that have never been named.

The Topographic maps give the altitude of many of these mountains or hills, but no name is to be found, all are simply known as "the Mountain" locally. Obviously all this applies mainly to the second list following.

The list immediately following is designed to enable anyone wishing a map of some town to know what sheet to order, or if necessary, sheets. As previously stated, these sheets can be ordered from the Director, U. S. Geological Survey, Washington, D. C., or often from a nearer bookstore, since there are several of these that carry the maps in stock.

LIST OF VERMONT TOWNS STATING IN WHAT QUADRANGLES, OR MAPS, EACH IS FOUND.

Name of Town.	Name of Topographic Sheet.	Part Given on the Map.
Abnaki	Rouses Point	All.
Adamant	Montpelier	All.
Addison	Port Henry	All.
Albany	Irasburg	North third.
Alburg	Rouses Point	All.
Andover	Wallingford	A very little of the west part.
Arlington	Equinox	Nearly the whole.
Athens	Not surveyed	
Bakersfield	Enosburg Falls	Nearly the whole.
Baltimore	Not surveyed	
Barnard	Woodstock	Southern half.
Barnet	Not surveyed	
Barre	Barre	Practically all.
Belvidere	Jay Peak	Northern part.
Bennington	Bennington	Nearly all.
Benson	Ticonderoga Whitehall	All.
Berkshire	Enosburg Falls Jay Peak	All.
Berlin	Montpelier Most Barre	All.
Bethel	Not surveyed	
Bloomfield	Not surveyed	
Bolton	Camels Hump	All.
Bradford	Not surveyed	
Braintree	Barre Rochester	All.
Brandon	Brandon	All.
Brattleboro	Brattleboro	All.
Bridgewater	Woodstock	All.
Bridport	Port Henry	All.
Brighton	Not surveyed	
Bristol	Middlebury	All.
Brookfield	Barre	A large part.
Brookline	Not surveyed	
Brownington	Lake Memphremagog	Nearly all.
Brunswick	Not surveyed	
Burke	Not surveyed	

Name of Town.	Name of Topographic Sheet.	Part Given on the Map.
Burlington	Burlington	All.
Cabot	Not surveyed	
Calais	Montpelier	A part only.
Cambridge	Not surveyed	
Canaan	Not surveyed	
Castleton	Castleton	All.
Cavendish	Not surveyed	
Charleston	Lake Memphremagog	Nearly all.
Charlotte	Burlington	All.
Chelsea	Strafford	Southeast half.
	Barre	Northwest part.
Chester	Not surveyed	
Chittenden	Rutland	Nearly all.
Clarendon	Rutland	Nearly all.
Colchester	Burlington	
	Milton	Nearly all.
Concord	Whitefield	Only little of southeast.
Corinth	Strafford	A little of south part.
Cornwall	Brandon	Large part.
Coventry	Lake Memphremagog	The larger part.
	Irasburg	East part.
Craftsbury	Not surveyed	
Danby	Pawlet	Nearly all.
Danville	Not surveyed	
Derby	Lake Memphremagog	All.
Dorset	Equinox	All.
	Pawlet	
	Londonderry	
Dover	Wilmington	All.
Dummerston	Brattleboro	All.
Duxbury	Camels Hump	Nearly all.
East Haven	Not surveyed	
East Montpelier	Montpelier	Western part.
Eden	Jay Peak	Northern part.
Elmore	Montpelier	Part.
Enosburg	Enosburg Falls	About half on each.
	Jay Peak	
Essex	Milton	Nearly all.
	Burlington	A little.
Fairfax	Milton	Mostly.
	St. Albans	A little.

Name of Town.	Name of Topographic Sheet.	Part Given on the Map.
Fairfield	St. Albans	A little.
	Enosburg Falls	Mostly.
Fairhaven	Whitehall	Nearly all.
Fairlee	Strafford	About a fourth.
Fayston	Camels Hump	A little.
	Lincoln Mountain	Mostly.
Ferrisburg	Burlington	North border.
	Port Henry	Mostly.
Fletcher	Enosburg Falls	Only a little.
Ft. Ethan Allen	Milton	All.
Franklin	Enosburg Falls	All.
Georgia	Milton	Nearly all.
Glastenbury	Equinox	North third.
	Bennington	All the rest.
Glover	Not surveyed	
Goshen	Brandon	Mostly.
	Rochester	A small part.
Grafton	Not surveyed	
Granby	Not surveyed	
Grand Isle	Plattsburg	Nearly all.
Granville	Lincoln Mountain	North part.
	Rochester	South part.
Greensboro	Not surveyed	
Groton	Not surveyed	
Guildhall	Not surveyed	
Guilford	Brattleboro	North two-thirds.
	Greenfield	South part.
Halifax	Brattleboro	Much, northern part.
	Greenfield	South border.
	Hawley	Southwest border.
	Wilmington	Northwest part.
Hanksville	Camels Hump	All.
Hancock	Rochester	All.
Hardwick	Not surveyed	
Hartford	Hanover	All.
Hartland	Hanover	Nearly all.
	Woodstock	Southwest corner.
Highgate	St. Albans	Nearly all.
	Enosburg Falls	Eastern part.
Hinesburg	Burlington	All.
Holland	Lake Memphremagog	Western part.
Huntington	Burlington	Western part.
	Camels Hump	Eastern part.

Name of Town.	Name of Topographic Sheet.	Part Given on the Map.
Hyde Park	Not surveyed	
Ira	Castleton	Nearly all.
	Pawlet	South end.
Irasburg	Irasburg	Large part.
	Lake Memphremagog	Eastern part.
Island Pond	Not surveyed	
Isle La Motte	Rouses Point	All.
Jamaica	Londonderry	Nearly all.
Jay	Jay Peak	Western part.
	Irasburg	Eastern part.
Jericho	Burlington	Southwest part.
	Camels Hump	Eastern part.
Johnson	Not surveyed	
Kirby	Not surveyed	
Landgrove	Londonderry	Southern border.
	Wallingford	Mostly.
Leicester	Brandon	All.
Lemington	Not surveyed	
Lincoln	Lincoln Mountain	West part.
	Middlebury	East part.
Londonderry	Londonderry	Nearly all.
Lowell	Jay Peak	Western part.
	Irasburg	Eastern part.
Ludlow	Not surveyed	
Lunenburg	Whitefield	Southeastern part.
Lyndon	Not surveyed	
Maidstone	Not surveyed	
Manchester	Equinox	All.
Marlboro	Brattleboro	Eastern part.
	Wilmington	Western part.
Marshfield	Not surveyed	
Mendon	Rutland	All.
Middlebury	Middlebury	North part.
	Brandon	South part.
Middlesex	Montpelier	All.
Middletown Sprs.	Castleton	North part.
	Pawlet	South part.
Milton	Milton	All.
Monkton	Burlington	North part.
	Middlebury	South part.
Montgomery	Jay Peak	All.
Montpelier	Montpelier	Nearly all.

Name of Town.	Name of Topographic Sheet.	Part Given on the Map.
Moretown	Montpelier	Northeast part.
	Barre	Southeast part.
	Lincoln Mountain	Very little.
	Camels Hump	Very little.
Morgan	Lake Memphremagog	Western part.
Morristown	Not surveyed	
Mount Holly	Wallingford	Nearly all.
Mount Tabor	Wallingford	All.
Newark	Not surveyed	
Newbury	Not surveyed	
Newfane	Brattleboro	Mostly.
	Wilmington	A little west.
New Haven	Middlebury	All.
Newport	Lake Memphremagog	Eastern part.
	Irasburg	Western part.
Northfield	Barre	Mostly.
	Lincoln Mountain	Very little.
North Hero	Rouses Point	All.
Norton	Not surveyed	
Norwich	Hanover	South part.
	Strafford	North part.
Orange	Not surveyed	
Orwell	Ticonderoga	Nearly all.
	Brandon	East border.
Panton	Port Henry	All.
Pawlet	Pawlet	All.
Peacham	Not surveyed	
Peru	Wallingford	Northern half.
	Londonderry	Southern half.
Pittsfield	Rutland	Southern part.
	Rochester	A little.
Pittsford	Rutland	Part.
	Castleton	Large part.
Plainfield	Not surveyed	
Plymouth	Rutland	West border.
	Woodstock	Northeast part.
Pomfret	Hanover	East part.
	Woodstock	West part.
Poultney	Castleton	North part.
	Pawlet	South part.
Pownal	Bennington	Nearly all.
	Berlin	A little.
	Greylock	South border.

Name of Town.	Name of Topographic Sheet.	Part Given on the Map.
Proctor	Castleton	All
Putney	Brattleboro	South part.
	Keene	Southeast part.
Randolph	Not surveyed	
Reading	Woodstock	North part.
Readsboro	Bennington	A little.
	Greylock	Southwest part.
	Hawley	Southern strip.
	Wilmington	East part.
Richford	Jay Peak	All
Richmond	Burlington	West part.
	Camels Hump	East part.
Ripton	Brandon	Most.
	Middlebury	A little.
Royalton	Stafford	Northeast part.
Rupert	Equinox	Southeast part.
	Pawlet	Northeast part.
	Cambridge	Southwest part.
Rutland	Rutland	East part.
	Castleton	West part.
St. Albans	St. Albans	Nearly all.
	Enosburg Falls	A little.
St. George	Burlington	All.
St. Johnsbury	Not surveyed	
Salisbury	Brandon	All.
Sandgate	Equinox	Nearly all.
	Cambridge	A little.
Searsburg	Wilmington	Nearly all.
Shaftsbury	Bennington	Southwest part.
	Cambridge	A little, northwest.
	Equinox	North part.
	Hoosick	West border.
Sharon	Hanover	Southeast part.
	Strafford	Nearly all.
Sheffield	Not surveyed	
Shelburne	Burlington	All.
Sheldon	St. Albans	East part.
	Enosburg Falls	Mostly.
Sherburne	Rutland	Nearly all.
	Woodstock	Eastern part.
Shoreham	Brandon	East part.
	Ticonderoga	Nearly all.
Shrewsbury	Rutland	Large part.
	Wallingford	South border.

Name of Town.	Name of Topographic Sheet.	Part Given on the Map.
Somerset	Londonderry	Northeast part.
	Wilmington	A large part.
South Burlington	Burlington	All.
South Hero	Plattsburg	All.
Springfield	Not surveyed	
Stamford	Bennington	Nearly all.
	Greylock	South border.
Stannard	Not surveyed	
Starksboro	Burlington	Northwest part.
	Middlebury	Large part.
Stockbridge	Rutland	Southwest part.
	Woodstock	Northwest part.
Stowe	Montpelier	Large part.
	Camels Hump	Southwest part.
Strafford	Strafford	All.
Stratton	Londonderry	Nearly all.
Sudbury	Brandon	Nearly all.
Sunderland	Equinox	All.
Sutton	Not surveyed	
Swanton	St. Albans	All.
Thetford	Strafford	More than half.
Tinmouth	Pawlet	All.
Topsham	Not surveyed	
Townshend	Not surveyed	
Troy	Irasburg	All.
Tunbridge	Strafford	More than half.
Underhill	Camels Hump	South part.
Vergennes	Middlebury	Eastern part.
	Port Henry	Western part.
Vernon	Brattleboro	Northern part.
	Greenfield	Southwest corner.
	Warwick	Southeast part.
Vershire	Strafford	Nearly all.
Victory	Not surveyed	
Waitsfield	Lincoln Mountain	Nearly all.
Walden	Not surveyed	
Wallingford	Wallingford	Nearly all.
Waltham	Middlebury	East part.
	Port Henry	West part.
Wardsboro	Londonderry	North part.
	Wilmington	South part.
Warren	Lincoln Mountain	All.

Name of Town.	Name of Topographic Sheet.	Part Given on the Map.
Washington	Not surveyed	
Waterbury	Camels Hump	West part.
	Montpelier	East part.
Waterford	Not surveyed	
Waterville	Not surveyed	
Weathersfield	Not surveyed	
Websterville	Barre	All.
Wells	Pawlet	Nearly all.
West Fairlee	Strafford	All.
Westfield	Irasburg	Eastern part.
	Jay Peak	Western part.
Westford	Milton	Western part.
West Haven	Whitehall	All.
Westminster	Not surveyed	
Westmore	Lake Memphremagog	Northwest part.
West Rutland	Castleton	All.
Weston	Londonderry	Southeast part.
	Wallingford	Nearly all.
Westville	Not surveyed	
West Windsor	Woodstock	Northwest part.
Weybridge	Middlebury	East part.
	Port Henry	West part.
Wheelock	Not surveyed	
Whiting	Brandon	All.
Whitingham	Wilmington	Nearly all.
Williston	Burlington	All.
Williamstown	Barre	Nearly all.
Wilmington	Wilmington	All.
Windham	Londonderry	West part.
Windsor	Hanover	North border.
Winhall	Londonderry	Nearly all.
	Equinox	Small strip.
Winooski	Burlington	All.
Wolcott	Not surveyed	
Woodbury	Not surveyed	
Woodford	Bennington	All.
Woodstock	Woodstock	Nearly all.
	Hanover	Northeast part.
Worcester	Montpelier	All.
Wrightsville	Montpelier	All.

Further explanation as to the use of the foregoing table is hardly needed, but to make sure that all is understood a word may be added. For example, if anyone wishes to find the general surface features of a certain town and its surrounding country, he should first obtain the map or maps on which these are shown and as there are many maps, he first of all needs to know which to buy. By reference to this table he finds without difficulty which maps to order, that is, suppose he wishes to know something about Fayston. He finds from the list that he must have the Lincoln Mountain map and this may be sufficient for his needs as most of the township is seen on the above sheet, but it may be that what is most wanted is in the extreme northern part of the town and that the Camels Hump Sheet is also needed. If all one wants is the general character of the region, he needs only this list, but if he needs the exact elevation of this or other parts of the State he must consult the following list.

As already stated, nearly all the altitudes given in the list are taken from the Topographical Maps of the U. S. Survey, but when, as in some few cases, the locality has not been surveyed this is stated, and when there has been a survey by competent engineers not of the U. S. Survey this is given.

The following abbreviations are used:

A. J. C.	A. J. Crosby, Superintendent, Springfield Railway.
Aneroid.	Heights taken by aneroid barometer.
B. A. R.	B. A. Robinson, Engineer, Bellows Falls.
Beers.	Beers' Map of Vermont.
B. and M. R. R.	Boston and Maine R. R.
C. P. R. R.	Engineers Canadian Pacific R. R.
C. V. R. R.	Engineers Central Vermont R. R.
M. C. R. R.	Engineers Main Central R. R.
M. and W. R. R. R.	Engineers Montpelier and Wells River R. R.
Rut. R. R.	Engineers Rutland R. R.
St. J. and L. C. R. R.	Engineers St. Johnsbury and Lake Champlain R. R.
U. Vt. E.	University of Vermont Engineers.
White.	James White, Canadian Engineer.
N. S.	Not yet surveyed and therefore unknown.

When no authority is given the figures are those of the U. S. Survey.

LIST OF ALTITUDES, MOUNTAINS AND TOWNS OF VERMONT.

Measurements mainly those of the United States Topographical Survey.

Locality.	Authority.	Altitude.
Ackworth, Bristol		630
Adam Pond, Jamaica		960
Adamant		1,060
Adams Pond, Enosburg		1,000
Adams Mountain, Granville		3,236
Addison		280
Ajers Hill, Berkshire		1,326
Albany, Brown School		920
Albany, Center School		1,265
Albany, Vance School		1,435
Albany Village		N. S.
Albany, White School		1,435
Alburg, Center		140
Alburg, Greenwood School		130
Alburg, R. R. Station		123.36
Alburg Springs		131
Alburg Station, 1.9 mile west on track		104.2
Alder Hill, Berkshire		1,326
Aldis Hill, St. Albans		840
Alfrecha		553
Algiers, Guilford		440
Allen Hill, Newport		1,100
Allen Hill, Irasburg		1,580
Allens Pond, Marlboro		N. S.
Ames Hill, Marlboro		1,862
Amsden Village		N. S.
Andover Village		....
Annis Hill, Chelsea		2,000
Anthony, Mount, Bennington		2,345
Antone Mountain, Rupert		2,660
Appalachian Gap, Huntington		2,300
Arlington Village		691
Arrowhead Mountain, Milton		947
Asbestos Mine, Belvidere Mountain		1,900
Ascutney Mountain, Windsor	A. D. Hagar	3,326
Ascutneyville		N. S.
Athens		N. S.
Austin Hill, Rochester		2,274
Austin Hill, West Haven		616
Austin Pond, Hubbardton		468

Locality.	Authority.	Altitude.
Averill		N. S.
Baby Stark Mountain, Huntington		2,620
Bailey Mills, Reading		1,060
Bald Hill, Huntington		2,900
Bald Hill, Pawlet		2,088
Bald Mountain, Bennington		2,865
Bald Mountain, Bridgewater		2,380
Bald Mountain, Lincoln		1,620
Bald Mountain, Mendon		2,087
Bald Mountain, Northfield		2,586
Bald Mountain, Westmore		3,310
Bald Mountain, West Haven		1,045
Bald Mountain, Woodford		2,885
Baldwin Mountain, Lunenburg		1,981
Ball Mountain, Jamaica		1,745
Baltimore		N. S.
Bakersfield, Basswood School		860
Bakersfield, Branch School		581
Bakersfield, Butternut Ridge School		1,280
Bakersfield, Cookes School		930
Bakersfield, Gidding Hill		1,280
Bakersfield, High School		640
Bakersfield, North School		1,060
Bakersfield, Number 2 School		560
Bakersfield, Number 9 School		418
Bakersfield, Number 11 School		700
Bakersfield, Ross School		620
Bakersfield Village, north part		680
Bakersfield, Woodmans Mill		500
Barber Hill, Charlotte		420
Barber Mountain, Middletown		1,541
Barber Pond, Pownal		1,100
Bare Hill, Putney		1,240
Bare Hill, Stamford		2,740
Barker Hill, Castleton		1,210
Barker Mountain, Middleton		1,395
Barnard, Lakota Lake		1,885
Barnard, Line Pond		1,460
Barnard, Morgan School	B. M.	1,140
Barnard Village, Methodist Church		1,334.5
Barnet, Town Hall	Aneroid	555
Barnet, Station	B. and M. R. R.	452
Barnum Hill, Shoreham		496
Barmunville, Manchester	B. M.	740
Barr Hill, Greensboro	U. Vt. Engineers	2,130.9

Locality.	Authority.	Altitude.
Barre City, Brookside School		1,040
Barre, Carleton School		1,195
Barre, City Hill, entrance		609.4
Barre, Cobble Hill School		1,700
Barre, Goldsboro School		N. S.
Barre, Corner High and East Streets		N. S.
Barre, Hospital		860
Barre, Lincoln School		1,020
Barre, Reservoir		940
Barre, West Hill School		1,000
Barre, Willey and Elm Streets end at Iron Bridge		563
Barton, Baird School		1,160
Barton, Fisk School		1,300
Barton, Devereux School		1,360
Barton Mountain		2,235
Barton, Reservoir		1,140
Barton, Riverside School		700
Barton Village	B. M.	931
Bartonsville	Rut. R. R.	487
Bates Hill, Beebe Plain		N. S.
Battell Lodge, Lincoln		3,420
Battell Mountain, Ripton		3,471
Bartonsville	Rut. R. R.	487
Basin Harbor, Store		120
Baxter Mountain, Sharon		1,530
Bear Mountain, Manchester		3,290
Bear Mountain, Wallingford		2,262
Bear Hill, Brookfield		2,000
Beckley Hill, Barre		1,040
Beckner Hill, Roxbury		2,260
Beebe Plain		800
Beebe Pond, Hubbardton		622
Beebe Pond, Sunderland		2,320
Beecher Falls, Canaan	M. C. R. R.	1093
Beldens Falls, Station		330
Bellows Falls, R. R. Station	Fitchburg R. R.	309
Bellows Falls, Corner Church and School Streets	B. A. R.	354
Bellows Falls, Front of High School	Aneroid	365
Bellows Falls, Front of Post Office	B. A. R.	324
Bellows Falls, North end of Hyde Street	B. A. R.	489
Bellows Falls, Public Playground	B. A. R.	429
Belmont, Mount Holly		1,820
Belvidere Center		943
Belvidere, Center School		523.58

Locality.	Authority.	Altitude.
Belvidere Corners		1,220
Belvidere Mountain		3,360
Belvidere Lumber Company's Mill, 1.9 miles north		1,965
Bellevue Hill, St. Albans		1,410
Bennington, Court House		682
Bennington, National Bank		672
Bennington, Monument		873
Bennington, Corner Main and Bradford Streets		752.4
Bennington, Pine Hills, 5 miles south		968.9
Bennington, 850 feet south of Deerfield River bridge		1,831
Benson		550
Benson Landing		120
Berkshire, Corey School		916
Berkshire, East Berkshire		460
Berkshire, School No. 10		756
Berkshire Village		440
Berlin Corners		1,016
Berlin Pond		972
Berlin, East Road School		1,000
Berlin, R. R. Station		617
Berlin, Reservoir		983
Berlin, West Hill		1,310
Bethel, Bethel Inn	Aneroid	595
Bethel, High School	Aneroid	600
Bethel, C. V. R. R. Station	Aneroid	572
Bethel, Town Hall	Aneroid	585
Bethel, W. R. R. R. Station		544
Biddle Knob, Pittsford		2,020
Big Falls, Troy		600
Big Pond, Woodford		2,263
Big Pond, Hyde Park		150
Big Spruce Mountain, Arlington		2,510
Billings Pond, Woodford		2,100
Bingham Hill, Bennington		740
Binghamville, Fletcher		N. S.
Birch Hill, Jericho		1,220
Bird Mountain, West Rutland		2,210
Birch Hill, Jericho		1,220
Black Mountain, Dummerston		1,269
Black Mountain, Granite Quarry, Dummerston		700
Black Pond, Hubbardton		625
Bliss Pond, Bolton		N. S.
Blissville, Castleton		480
Bliss Pond, Montpelier		1,209
Blodgett Mountain, Stamford		2,500

Locality.	Authority.	Altitude.
Bloomfield		N. S.
Bloodroot Mountain, Chittenden		3,520
Blossoms Corners, Pawlet		421
Blueberry Hill, Pittsford		1,724
Blueberry Ledge, Plymouth		1,660
Blueberry Hill, Plymouth		2,160
Blue Ridge Mountain, Mendon		3,293
Boardman Hill, Clarendon		1,315
Bolton, R. R. Station, top of rail		341.9
Bolton, R. R. Bridge No. 76		342.2
Bolton Falls, Waterbury		400
Bolton, Fiddock School		360
Bolton Mountain		3,725
Boltonville	M. and W. R. R. R.	624
Bomoseen Lake		413
Bondville, Winhall		1,240
Bondsville, Mt. Holly		1,280
Bone Mountain, Bolton		2,900
Bourn Pond, Sunderland		2,400
Bowlsville, Mount Holly		1,300
Bordoville, Enosburg		740
Bradford, Station, top of rail		405
Bradley Hill, Norwich		1,220
Bragg School, Norwich		1,060
Braintree, R. R. Station	C. V. R. R.	777
Braintree Village		787
Branch Pond, Sunderland		2,620
Brandon, R. R. Station		394
Brandon, Brandon Inn		420
Brandon, Bridge over Mill Creek		416.4
Brandon, R. R. Bridge, 3.4 miles south		362
Brandon Gap, Goshen	B. M.	2,184
Brattleboro, Canal Street School		295
Brattleboro, Elm Street Bridge		245
Brattleboro, Corner Elm and Prospect Streets		320
Brattleboro, Front of High School		295
Brattleboro, Post Office		260
Brattleboro, Retreat		220
Brattleboro, Reservoir		380
Breadloaf Inn		1,400
Breadloaf Mountain		3,823
Breese Pond, Hubbardton		555
Breezy Hill, Derby		1,100
Bridgewater, Center		940
Bridgewater, Corners		321

Locality.	Authority.	Altitude.
Bridgewater, Chateaugay	B. M.	1,417
Bridgewater, English Mills		800
Bridgewater, Mendall School		1,680
Bridgewater, Riverside School		954
Bridgewater Village		820
Bridport, Grange Hall		345
Briggs, Bridgewater		940
Briggs Corners, Shaftsbury		1,820
Brigham Hill, Essex		1,032
Brighton		N. S.
Bristol, Casket Factory		510
Bristol Flats		376
Bristol, Gilmore Pond		2,020
Bristol, Higgins Pond		1,680
Bristol, Hotel		575
Bristol, R. R. Station		570
Brocklebank Hill, Tunbridge		2,120
Brockways	Rut. R. R.	462
Bromley Mountain, Peru		3,260
Brookfield, Bear Hill School		1,572
Brookfield, Bowman School		1,460
Brookfield Center		1,441
Brookfield, Keyes School		1,857
Brookfield, North Branch School		714
Brookfield, Number 12 School		2,000
Brookfield, South Branch School		580
Brookfield, West Street School		1,422
Brookline		N. S.
Brookside		N. S.
Brooksville, New Haven		240
Brookville	C. V. R. R.	301
Brown Pond, Sunderland		2,500
Brownington Pond		991
Brownington, Brown Pond		2,500
Brownington, Powers School		1,241
Brownington Village		1,249
Brownsville, West Windsor		N. S.
Browns Ledges, Lowell		1,680
Browns Mountain, Starksboro		2,309
Browns Pond, Bakersfield		648
Brunswick		N. S.
Brush Hill, Stowe		1,120
Bryant Mountain, Salisbury		1,122
Bryant Mountain, Wallingford		1,120
Buck	S. J. and L. C. R. R.	504

Locality.	Authority.	Altitude.
Buck Hollow, Fairfax		600
Buck Mountain, Waltham		927
Bucketville, Wardsboro		1,100
Bucks Cobble, Shaftsbury		1,400
Bull Hill, Castleton		920
Bull Hill, Bridgewater		2,320
Bunker Hill, Pomfret		1,360
Burke		N. S.
Burke Mountain	Beers Atlas	3,500
Burleson Pond, Berkshire		600
Hadley Mountain, Lowell		2,400
Burlington, West step City Hall	B. M.	208
Burlington, Green Mount Cemetery		313
Burlington, Lake View Cemetery		228
Burlington, Corner Main and Champlain Streets		151
Burlington, Corner Main and St. Paul Streets		190
Burlington, Corner Main and South Union Streets		226
Burlington, Corner Main and South Prospect Streets		364
Burlington, Converse Dormitory, U. V. M.		373
Burlington, Union Station		120
Burlington, Weather Bureau		381
Burlington, Williams Science Hall, U. V. M.		369
Burnhampton, Monkton		470
Burr Pond, Pittsford		1,180
Burnell Pond, Brandon		500
Burnt Hill, Hancock		3,120
Burnt Hill, Pawlet		1,080
Burnt Hill, Rupert		2,500
Burnt Mountain, Montgomery		2,666
Burnt Mountain, Fayston		3,168
Burr Pond, Pittsford		1,180
Butlers Corners, Essex		519
Bush Pond, Sharon		1,280
Butler Pond, Pittsford		660
Button Hill, Wallingford		2,040
Cabot		N. S.
Cadys Falls, Morriston		N. S.
Cady Hill, Stowe		1,140
Calais, Bliss Pond		1,309
Calais, Bliss Cemetery	R. Aneroid	1,030
Calais, Kents Corners	R. Aneroid	1,210
Calais, Curtis Pond		1,214
Calais, Long Meadow Hill, North Peak		2,020
Calais, Number 7 School		1,312
Calais, West Hill Church	R. Aneroid	1,335

Locality.	Authority.	Altitude.
Cambridge Junction	St. J. and L. C. R. R.	461
Cambridge, Main Street	Aneroid	498
Cambridge, R. R. Station	C. V. R. R.	454
Cambridgeport		N. S.
Camels Hump Mountain, Duxbury		4,083
Canaan		N. S.
Cape Lookout Mountain, Goshen		3,298
Cargill Hill, Morgan		2,700
Carmel Mountain, Chittenden		3,341
Carpenter Hill, Pownal		1,640
Carter Hill, Highgate		380
Carver Falls, West Haven		126
Caspian Lake, Greensboro	U. V. M. E.	1,404.2
Castleton, Blissville		460
Castleton Corners		460
Castleton, Hydeville		406
Castleton, Ransomville		700
Castleton, R. R. Station		441
Castleton, West Village		440
Catamount Cobble, Sunderland		2,360
Cavendish, R. R. Station	Rut. R. R.	929
Cedar Beach, South part		160
Center, R. R. Station		774
Center Rutland, R. R. Station		536
Centervale, St. Johnsbury	Aneroid	610
Centerville, Hartford		394
Centerville, Hyde Park		....
Center Hill, Thetford		1,593
Central Mountain, Marlboro		2,006
Chaffee Mountain, Chittenden		2,506
Chamberlain Hill, Richmond		920
Chamberlain Glen, Huntington		2,500
Chamberlain Hill, Irasburg		1,300
Champlain, Lake, Mean water		96
Champlain, Lake, High water	White	103
Champlain, Lake, Low water (October)	White	92.2
Charlotte, Alexander Corners		365
Charlotte, Center		361
Charlotte, One-fourth mile east of Post Office		252.5
Charlotte, R. R. Station		180
Charlestown, Center School		1,196
Charlestown, Cole Hill School		1,180
Charlestown, Gay Hill School		1,410
Charlestown, Oliver Hill School		1,470
Charlestown, Plunkett School		1,167

Locality.	Authority.	Altitude.
Charlestown, Powers School		1,241.6
Charlestown, Number 7 School		1,400
Chateaugay, Bridgewater, School at three corners		1,416.6
Chase Mountain, Middlebury		2,280
Chase Mountain, Moretown		2,060
Checkerberry, Milton		780
Chelsea Village		860
Chelsea, Weather Bureau		1,350
Chester Depot,	Rut. R. R.	599
Chester Village	Beers	501
Childs Hill, Thetford		1,306
Childs Mountain, Granville		2,800
Chimney Point, Addison		20
Chipman Hill, Middlebury		820
Chipmans Point, Orwell		140
Chippenhook, Clarendon		860
Chiselville, Sunderland		800
Chittenden, Michigan Camp		1,400
Chittenden, North		1,000
Chittenden, Steam Mill School		1,500
Chittenden Village		1,180
Choate Pond, Orwell		960
Christian Hill, Bethel		N. S.
Clarendon		580
Clark Hill, West Rutland		1,600
Clark, Sutton		N. S.
Clark Mountain, Tinmouth		1,961
Clarke Mountain, Underhill		3,160
Cleveland Hill, Coventry		1,460
Cleveland Hill, Pawlet		1,300
Cliff Haven Camp, Newport		700
Cloverdale, Underhill		N. S.
Coates Island, Malletts Bay		100
Cobb Hill, Bridgewater		1,960
Cobb Hill, Ripton		2,300
Cobb Pond, Derby		1,121
Cobble Hill, Jericho		700
Cobble Hill, Lincoln		3,140
Cobble Hill, Londonderry		1,907
Cobble Hill, Milton		860
Cobble Hill, Rochester		1,080
Cobble Hill, Wells		1,510
Cobble Hill, Weston		907
Coburn Hill, Irasburg		893
Colbyville, Waterbury, opposite Second Advent Church		593.9

Locality.	Authority.	Altitude.
Colchester Center, Main Crossroads		273.6
Colchester Pond		366
Colchester, R. R. Station	B. M.	328
Cold River, Clarendon		553
Cold River, Shrewsbury		850
College Hill, Jamaica		2,051
Colton Hill, Vershire		2,412
Comptois Hill, Shrewsbury		2,020
Concord, Southeast part		1,190
Conicut, Newbury		N. S.
Cooks Hill, Greensboro	U. V. M. E.	1,730.7
Cooks Hill, Strafford		1,685
Cooley Gun Club, Lincoln		3,140
Cooper Hill, Dover		2,606
Copperas Hill, Shrewsbury		1,861
Copperas Hill, Strafford		1,160
Copperfield		960
Copper Flat, Strafford		860
Corinth		N. S.
Cornwall, Library		365
Cornwall, Town Hall		374
Cornwall, Bridge three miles east of village		349.5
Corporation Mountain, Chittenden		3,000
Coventry, Center School		800
Coventry Village	B. M.	718
Coventry, West Hill School		740
Coy Mount, Wells		2,060
Crawford Hill, Charleston		1,546
Craftsbury Corners	Beers	1,159
Cream Hill, Bridport		420
Crookhite Hill, Monkton		640
Crystal Pond, Barton		988
Cudding Hill, Shoreham		500
Curtis Hill, Tunbridge		1,561
Cushman Hill, Georgia		1,087
Cushman Mountain, Rochester		2,791
Curtis Pond, Calais		1,760
Cutler Pond, Highgate		250
Cutler Pond, Williamstown		912
Cuttingsville		1,047
Cutts Park, Warren		3,300
Dailey Hollow, Bridgewater		1,150
Dana Hill, Pomfret		1,380
Danby		680

Locality.	Authority.	Altitude.
Danby Four Corners		1,440
Danby Hill		2,112
Danby Pond		1,400
Danville, Post Office	Aneroid	1,420
Danville, R. R. Station	St. J. and L. C. R. R.	1,341
Davis Bridge, Whitingham		1,360
Davison Hill, Strafford		1,740
Deer Knoll, Manchester		1,620
Delano Hill, Shoreham		610
Delectable Mountain, Barnard		2,660
Densmore Mountain, Middlesex		2,720
Derby, Bates School		1,220
Derby, Black School		1,140
Derby, Breezy Hill School		1,100
Derby, Line School		983
Derby, Pine Hill School		954
Derby, Post Office		720
Derby Village	B. M.	1,011
Derby Line, Custom House		1,028.9
Derby Line, Four Corners		1,243
Derby Line, Reservoir		1,260
Derby Line Village	B. M.	1,029
Deweys Mills, Quarry, Hartford		1,080
Diamond Hill, Milton		540
Doctor Hill, Enosburg		1,000
Dome, Pownal		2,754
Dorset Mountain		3,436
Dorset Peak, Danby		3,804
Dorset Pond		720
Dorset Village		940
Dorset, East		1,100
Dorset, South		920
Dothan, Hartford		940
Double Top Mountain, N. E. Peak	Warren	1,720
Doughty Pond, Benson		700
Dover, Church		1,895
Dover, East		1,100
Dover, West		1,720
Dows, Walden, R. R. Station	S. J. and L. C. R. R.	1,411
Dow Hill, Hinesburg		1,231
Dow Pond, Middlebury		440
Dowling Hill, Derby		1,345
Downingsville, Lincoln		1,324
Dowsville, Duxbury		1,288

Locality.	Authority.	Altitude.
Drinkwater Hill, Roxbury		2,040
Dummerston, Church		778
Dummerston, R. R. Station		260
Dummerston Village		740
Dumpling Hill, Worcester		1,960
Dunsmore Lake, Salisbury		571
Dunsmore Lodge, Bolton		2,640
Dutch Hill, Danby		2,480
Duxbury, Durkee School		1,200
Duxbury, North		400
Duxbury, Scrabble Hill School		797
Duxbury Village		420
Eagle Ledge, Vershire		1,859
Eagle Mountain, Milton		600
East Alburg	B. M.	116
East Arlington		740
East Barnard		N. S.
East Barnet		N. S.
East Barre		1,128
East Berkshire, Bridge near Water Tank		404
East Berkshire, Front of School Building		439.7
East Berkshire, Station front		431
East Berkshire Village		460
East Bethel		N. S.
East Braintree		N. S.
East Brighton		1,159
East Brookfield, Branch School	B. M.	714
East Brownington, School Building		1,360
East Burke	Aneroid	830
East Calais		N. S.
East Cambridge		N. S.
East Charlotte		375
East Charlestown		1,222
East Clarendon		780
East Concord	S. J. and L. C. R. R.	876
East Corinth		N. S.
East Craftsbury		N. S.
East Dorset		788
East Dover, Church		1,115
East Enosburg		700
East Fairfield, School Number 2		620
East Fairfield, School Number 9		420
East Fairfield, Station	St. J. and L. C. R. R.	371
East Fletcher		674

Locality.	Authority.	Altitude.
East Franklin		634
East Georgia	B. M.	354
East Granville		1,200
East Granville, R. R. Station		850
East Hardwick	St. J. and L. C. R. R.	1,031
East Haven		N. S.
East Highgate		220
East Hill, Tunbridge		1,540
East Hubbardton		960
East Jamaica		N. S.
East Kansas, Sunderland		940
East Middlebury, Hotel		475
East Monkton		660
East Montpelier, Center		1,100
East Mountain, Guildford	Beers	1,424
East Mountain, Mendon		2,390
East Mountain, Sherburne		2,812
East Mountain, Starksboro		1,520
East Peacham	Aneroid	940
East Pittsford		1,000
East Poultney		480
East Putney Village		380
East Putney, R. R. Station		280
East Randolph Village		691
East Richford		540
East Roxbury		1,909
East Rupert		840
East Ryegate	B. and M. R. R.	475.4
East St. Johnsbury	St. J. and L. C. R. R.	786
East Sheldon		578
East Shoreham		276
East Swanton, Station		155
East Thetford	B. and M. R. R.	405
East Wallingford		1,234
East Wells		1,060
East Wilmington		1,820
Echo Pond, Charleston		1,237
Eden, Corners School		1,141
Eden Mills		1,198
Eden, North Road School		1,430
Eden Village	B. M.	1,111
Edgerton Hill, Pawlet		1,220
Egg Mountain, Sandgate		2,510
Elbow, Woodford		2,587

Locality.	Authority.	Altitude.
Elkhurst Station	C. P. R. R.	672.7
Ellen Mountain, Warren		4,135
Elligo Pond, Craftsbury	Aneroid	890
Elligo Pond, Lower	Aneroid	860
Elm Hill, Derby		1,400
Elmore, Opposite Post Office		1,145.4
Elmore, Number 6 School		1,120
Ely, R. R. Station, top of rail	C. P. R. R.	430
Emerson, Rochester, R. R. Bridge, 1.4 miles S. E. Station		781.98
Emerson, Rochester, in front of Station		793
English Mills, Woodstock		840
Enosburg Center		875
Enosburg, Duffy Hill School		949
Enosburg Falls		400
Enosburg Falls, in front of Station		426.7
Enosburg, Gilbert's Tannery		460
Enosburg, Number 2 School		440
Enosburg, Woodward School		800
Equinox Mountain, Manchester		3,816
Essex, Beecher School		460
Essex, Brigham Hill School		640
Essex, Butlers Corners		519
Essex, Nichols School		520
Essex Center Village		492
Essex, Warner School		520
Essex Junction, Station		358
Essex Junction, Old Brick School		357
Ethan Allen Park, Base of Tower		300
Evarts, Hartland	B. M.	383
Evansville, Brownington		349
Evansville, Brownington, Base of gasoline pump at Hunts		115.8
Fairfax, School Number 11		460
Fairfax Village		349
Fairfield, Callan School		520
Fairfield, District 22 School		332
Fairfield, Gould School		577
Fairfield, McCarty School		800
Fairfield, Soule School		626
Fairfield, Station		389
Fairfield Village		500
Fairhaven, Inman Pond		640
Fairhaven, Station		360

Locality.	Authority.	Altitude.
Fairhaven, Village Square		400
Fairlee, Beanville		860
Fairlee, R. R. Station		435.5
Fairmount, East Montpelier		766
Fan Hill, Wells		1,731
Farman Hill, Lowell		1,380
Farmingdale, Middlebury		383
Fays Corners, Richmond	B. M.	563
Fayston, Number 6 East School		1,200
Fayston, Number 1 School		1,412
Fayston, Number 3 School		1,640.4
Fayston Village		1,208.6
Faysville, Glastonberry		1,840
Ferdinand, Essex		N. S.
Fennville, Leicester	B. M.	583
Fern Lake, Leicester		571
Ferrisburg, Foundation of Town Hall		217
Ferrisburg, North	B. M.	168
Fisk, Isle La Motte		120
Fishers Switch	Rut. R. R.	317
Flat Rock, Clarendon		1,285
Fletcher		424
Fletcher, Bridport		373
Fletcher Hill, Woodstock		1,840
Florence, Pittsford		380
Florona Mountain, Monkton		660
Forbes Hill, West Haven		540
Forestdale, Brandon		595
Fort Ethan Allen, Colchester		317
Fox Cobble, Pawlet		1,611
Fox Hill, Fairfield		780
Fox Hill, Milton		380
Fox Pond, Wallingford		580
Franklin, Browns Corners		285
Franklin, Bridgeman Hill		840
Franklin, Brown School		325
Franklin, Hubbard School		300
Franklin, Pomeroy School		520
Franklin Village	B. M.	426
Franklin, Front of Library		452.5
Fuller Mountain, Monkton		920
Gallup Hill, Montpelier		1,258
Gallup Mills, Victory		N. S.
Garfield, Hyde Park		N. S.
Garland Camp, Pittsfield		1,381

Locality.	Authority.	Altitude.
Gaskill, Waterford		N. S.
Gassetts, Station	Beers	715
Gaysville, Abutment of Highway Bridge over White River		696.6
Gaysville, One mile northeast on boulder, edge of track		623
Georgia Center, Brick Church		259
Georgia, Everett School		160
Georgia, Plains		259
Georgia, School Number 2		280
Georgia, Station, one mile south of		372.9
Giddins Hill, Bakersfield		1,300
Gile Mountain, Norwich		1,917
Gilette Hill, Hartford		1,220
Gilespie Mountain, Granville		2,928
Gilman Hill, Vershire		2,065
Gilmore Pond, Bristol		2,000
Ginseng Hill, Brattleboro		1,556
Glastenbury Mountain		3,764
Glebe Mountain, Londonderry		2,944
Glen Ellen, Fayston		3,400
Glen Lake, Castleton		480
Glenton, Glover	White	526
Glover		N. S.
Goodhue Ledge, Vershire		1,820
Goodwin Mountain, Westmore		2,935
Gorhamtown, Poultney		660
Goshen, South end of Church		1,136
Goshen, Four Corners		1,408
Goshen, In Brandon Gap at Summit		2,183
Goshen Mountain		3,266
Gove Hill, Thetford		1,362
Government Hill, Sudbury		1,075
Governor Mountain, Guilford		1,823
Grafton		N. S.
Graham Hill, Castleton		680
Granby		N. S.
Grand Isle Village		160
Grand Isle, Iodine Springs House		120
Grand Isle, Ladds Point		140
Grangeville, Pittsford		500
Grandmadam Hill, Bridgewater		1,980
Granite Hill, Wallingford		2,007
Graniteville, Barre		1,270
Grant, Westminster		2,007
Granville, Notch		1,280

Locality.	Authority.	Altitude.
Granville, North Hollow School		1,495
Granville, North abutment of Bridge over White River		1,013
Granville, Texas Gap		2,121
Granville, Texas School		1,845
Granville Village	B. M.	1,013
Grannyhand Hill, Strafford		1,710
Grass Mountain, Arlington		2,800
Grass Pond, Plymouth		1,560
Green Hill, Wallingford		1,213
Green Mount, Mt. Tabor		2,340
Green Mountain, Wallingford		2,509
Green Peak, Dorset		3,185
Green River, Church	B. M.	749
Greensboro, Caspian Lake House	U. V. M. E.	1,463.4
Greensboro, Caspian Lake, low water	U. V. M. E.	1,404.4
Greensboro, Lower step, Town Hall	U. V. M. E.	1,420.5
Greensboro, Station	U. V. M. E.	1,247.9
Greens Corners, Swanton		405
Greens Corners, Baptist Church		408
Greens Corners, On track two miles northwest		452.8
Green Hill, Wallingford		1,213
Green River, Guildford		740
Greenvale, Thetford		N. S.
Gregg Hill, Stowe		1,100
Griffith, Mt. Tabor		1,640
Griggs Mountain, Norwich		1,800
Griggs Pond, Albany		860
Groton Pond	M. and W. R. R. R.	1,094
Groton, Station (Lakeside)	M. and W. R. R. R.	771
Grout, Station	B. and M. R. R.	251
Grout Pond, Stratton		2,225
Grove, Halifax		1,460
Guildhall	Me. C. R. R.	874
Guildhall Falls	Beers	833
Guilford Center		708
Guilford, Church		410
Guilford, Green River		740
Guilford, Hinesburg		940
Hadley Mountain, Lowell		2,400
Hager Hill, Woodford		2,800
Hale Hollow, Plymouth		960
Hale Mountain, Shaftsbury		1,420
Halfmoon Pond, Hubbardton		586
Halifax, Church		1,900
Halifax, Grove		1,360

Locality.	Authority.	Altitude.
Hammond Hill, Mt. Holly		1,721
Hammondsville, Reading		1,376
Hancock, Branch School		1,040
Hancock, Highway Bridge over White River		912
Hancock, Middlebury Gap		2,149
Hancock Village, Cross Roads		912
Hancock Mountain		2,089
Hanksville, Huntington	B. M.	849
Hanksville, Two miles south of School		1,144
Hanksville, Fayston-Huntington Pass		2,217
Hardwick	S. J. and L. C. R. R.	861
Hardwick Hollow	Beers	720
Hardwood Flats, Elmore		1,280
Hardwood Pond, Elmore		1,563
Harmony Hill, Woodford		2,375
Harrington Hill, Danby		2,318
Harrington Cobble, Shaftsbury		1,460
Hartford, Birch School		941
Hartford, Bragg School		950
Hartford Center, Town School	B. M.	834
Hartford, Centerville	B. M.	394
Hartford, Deweys Mills, Station		550
Hartford, Dothan		840
Hartford, Jericho		1,065
Hartford, Podunk		400
Hartford, Savage Hill		1,269
Hartford Village		400
Hartford, Sprague Hill		1,200
Hartland, Four Corners, Church		617.5
Hartland, Station		441
Hartland Village		582
Harvey Pond	Aneroid	870
Haverhill	B. and M. R. R.	404
Hawkins Pond, Calais		1,420
Haynes Hill, Middletown		1,260
Haystack Mountain, Pawlet		1,919
Haystack Mountain, Lowell		3,223
Haystack Mountain, Westmore		2,767
Haystack Mountain, Wilmington		3,462
Haystack Pond, Wilmington		2,660
Hazen Notch, north end, Lowell		1,200
Healdville, Station	Rut. R. R.	1,432
Heartwellville, East of Post Office		1,784
Heartwellville, Readsboro Iron Bridge		1,363

Locality.	Authority.	Altitude.
Heartwellville, Two and one-half miles north on main road		2,446
Hectorville, Montgomery		800
Hedgehog Hill, Mt. Holly		2,295
Hedgehog Mountain, Westmore		2,225
Herrick Mountain, Ira		2,727
Hersey Hill, Calais		2,000
Hewetts Corners, Pomfret		1,140
Highgate Center	B. M.	310
Highgate Falls		300
Highgate, Forest School		303.9
Highgate, High School		307.3
Highgate, Post Office		225
Highgate Springs		127
Highgo Hill, Pawlet		1,318
High Knob, Shaftsbury		1,320
High Pond, Hubbardton		800
High Pond, Sudbury		820
Hillsboro Mountain, Starksboro		2,500
Hinesburg, Church		922
Hinesburg, Guilford		940
Hinesburg Pond		684
Hinesburg, Town Hall		343
Hinkum Pond, Sudbury		717
Hoag Mountain, Danby		2,240
Hobart Mountain, Worcester		1,960
Hogback Mountain, Bristol		1,850
Hogback Mountain, Goshen		2,290
Hogback Mountain, Marlboro		2,347
Hogback Mountain, Monkton		1,620
Hogback Mountain, Stowe		3,440
Holden, North Chittenden		1,000
Holland, Bazinet School		1,505
Holland, Green School		1,150
Hoosac Range, Stamford, highest peak		3,014
Hoosac Range, Rupert		2,809
Holland, South Holland School		1,462
Holland Village		1,405
Holt Hill, Chelsea		1,775
Hooker Hill, Castleton		860
Hopkinson Hill, Derby		1,300
Horrid Mountain, Goshen		3,140
Horsey Hill, Montpelier		2,000
Horton Pond, Hubbardton		488
Hortonville, Hubbardton		480

Locality.	Authority.	Altitude.
Hortonville, Orwell		N. S.
Howard Hill, Benson		661
Hubbard Hill, Thetford		1,682
Hubbardton Village		433
Huckleberry Hill, Richmond		1,520
Huffs Crossing, Orwell		228
Huff Pond, Sudbury		772
Hunger Mountain, Barnard		2,360
Huntington Center, at Covered Bridge		675.8
Huntington Gap		2,217
Huntington Village, Steps of Hines store		622.8
Hurricane Hill, Hartford		1,220
Hurricane Hill, Woodstock		1,160
Hutchins, Montgomery	B. M.	674
Hutchins, School, Montgomery		1,200
Hyde Manor, Sudbury		823
Hyde Park, R. R. Station	St. J. and L. C. R. R.	576
Hydeville, Castleton		406
Independence Mountain, Shoreham		300
Indian Hill, Pawlet		1,007
Inman Pond, Fairhaven		640
International Boundary, N. E. of Richford	White	508
International Boundary, N. W. of Richford	White	495
Inwood, Barnet	B. and M. R. R.	504.2
Ira		840
Ira Allen Mountain, Duxbury		3,506
Irasburg, Brighton School		900
Irasburg, Kidder School		900
Irasburg, Morrill Hill School		980
Irasburg Village		847
Irasburg, White School		1,100
Irasville, Waitsfield		789
Irish Hill, Berlin		1,340
Island Pond, R. R. Station	G. T. R. R.	1,178
Isle La Motte, Fisk		120
Isle La Motte, Light House		120
Isle La Motte, The Head		240
Jackson Corners, Williamstown		884
Jacksonville, Whitingham		1,400
Jamaica Village		700
Jamaica, Rawsonville		1,070
Jamaica, East		1,540
Jay, North Jay School		1,000
Jay Peak		3,861
Jay Village, Cross roads		922

Locality.	Authority.	Altitude.
Jeffersonville, Hotel	Aneroid	510
Jeffersonville, Station	C. V. R. R.	460
Jeffersonville Village		N. S.
Jericho, Bridge at Corners		500
Jericho Center, Steps of Church		765
Jericho, Congregational Church		N. S.
Jericho, Number 5 School		720
Jericho, Station		N. S.
Jericho, Hartford		1,066
Jerusalem Village, Starksboro		1,498
Jilson Hill, Whitingham		2,251
Jockey Hill, Shrewsbury		2,671
Joes Pond, Cabot	Aneroid	1,544
Johnson, Station	S. J. and L. C. R. R.	531
Johnson, Hotel	Aneroid	510
Johnson Pond, Orwell		445
Jonesville	B. M.	326
Jones Hill, Charlotte		600
Jones Mountain, Rochester		2,069
Kansas, Sunderland		2,240
Kelley Stand, Sunderland		2,240
Kent Hill, Hartland		1,660
Kew Hill, Waitsfield		1,900
Kibling Hill, Strafford		1,424
Kidder Pond, Irasburg		1,170
Killington Mountain		4,241
Killams Corners, 15 feet west of bridge		675
Kirby		N. S.
Kirby Peak, Ripton		3,000
Laisdell Hill, Jericho		1,080
Lake Bomoseen, Castleton		413
Lake Champlain, Dock, C. T. Company, July		94.39
Lake Champlain, High water		103
Lake Champlain, Low water		92.2
Lake Dunmore, Salisbury		571
Lake Mansfield, Stowe		1,140
Lake Memphremagog, Newport		665
Lake Morey, Fairlee		N. S.
Lake Park, Derby		700
Lake St. Catherine, Poultney		477
Lake Seymour, Morgan		1,279
Lake Willoughby, Westmore		1,169
Lakeside	M. and W. R. R. R.	1,094
Lakota Lake, Barnard		1,885
Lamson Pond, Brookfield		1,555

Locality.	Authority.	Altitude.
Landgrove		1,280
Lanesboro	M. and W. R. R. R.	1,347
Leeland Hill, Lowell		1,720
Leicester Junction, R. R. crossing north of Station		353
Lemington		N. S.
Lewis, Essex County		N. S.
Lewiston, Norwich		440
Liberty Hill, Pittsfield		1,620
Lighthouse Hill, Williamstown		1,857
Lilly Hill, Stockbridge		1,586
Lilly Pond, Danby		1,500
Lilly Pond, Vernon		380
Lincoln, Alder Hill School		1,412
Lincoln, Bridge		758
Lincoln Gap		2,424
Lincoln, Murray School		1,310
Lincoln, Lumber Company's store		971
Lincoln Hill, Wells		1,380
Lincoln Mountain		4,024
Line Pond, Barnard		1,460
Line Pond, Stockbridge		1,380
Linwood	Aneroid	495
Little Ascutney, Windsor	Beers	1,200
Little Killington, Mendon		3,951
Little Pico, Rochester		2,115
Little Pico, Sherburne		3,134
Little Pond, Benson		502
Little Pond, Wells		477
Little Pond, Winhall		2,390
Little Round Top, Stratton		3,440
Little Wilcox Peak, Pittsfield		2,729
Londonderry		1,100
Long Meadow Hill, Montgomery		2,120
Long Pond, Eden		1,137
Long Pond, Milton		297
Long Pond, Westmore		1,835
Lookoff Mountain, Chittenden		2,600
Loomis Hill, Waterbury		1,340
Lost Lake, Georgia		480
Lost Mountain, Granville		2,580
Lost Pond, Belvidere		2,500
Lowell, Congregational Church steps		995.9
Lowell, Richards School		1,215
Lowell Village	B. M.	996
Lowell Lake, Londonderry		1,200

Locality.	Authority.	Altitude.
Lower Cabot		N. S.
Lower Granville		962
Lower Rochester		800
Lower Waterford		N. S.
Luce Hill, Stowe		1,660
Ludlow, Station	Rut. R. R.	1,064
Ludlow Village		N. S.
Ludlow Mountain, Mount Holly		3,372
Lunenburg, R. R. Bridge		846
Lunenburg Village		844
Lyford Pond, Walden	Beers	1,692
Lyndon Center		N. S.
Lyndon Village		N. S.
Lyndonville, Station	B. and M. R. R.	727
McAllister Pond, Lowell		1,660
McIndoes, Station	Beers	488
McIndoes Falls, Barnet	B. and M. R. R.	441
McIntyre, Sunderland		2,060
McMaster Hill, Strafford		1,960
Maidstone		865
Malletts Head, Colchester		300
Manchester, Barnumville		740
Manchester, Beartown		1,400
Manchester Center		740
Manchester Depot		690
Manchester, Village Street		880
Mansfield Mountain Chin, last survey 1924		4,393
Mansfield Mountain, Nose		4,075
Maple Hill, Shaftsbury		1,706
Maple Hill, Woodford		2,740
Maquam		108
Markham Mountain, Andover		2,489
Markham Mountain, Weston		2,480
Marlboro, Church		1,736
Marlboro, Highest point on Wilmington Road		2,210
Marshfield Station	M. and W. R. R. R.	1,140
Marshfield, Hotel	Aneroid	750
Marsh Hill, Ferrisburg		340
Mason Hill, Pownal		1,606
Mason Hill, Sherburne		260
Masters Mountain, Rupert		2,410
Maxfield Lighthouse, Lake Memphremagog		700
May Pond Mountain, Westmore		2,100
Mead Hill, Holland		1,700
Mechanicsville, Hinesburg		436

Locality.	Authority.	Altitude.
Mechanicsville, Mt. Holly		1,820
Mecawee Pond, Reading		1,440
Meetinghouse Hill, Norwich		1,201
Meetinghouse Hill, Woodstock		1,660
Meister Hill, Franklin		800
Memphremagog, Lake		682
Mendon Peak, Mendon		3,837
Merrill Hill, Chelsea		1,390
Middlebury, Addison House		390
Middlebury, Battell Block		366
Middlebury, Mead Chapel		455
Middlebury, Station		355
Middlebury, Women's Dormitory, College		457
Middle Mountain, Pawlet		1,965
Middlesex Center		1,200
Middlesex, Culver School		1,000
Middlesex, Dudley School		1,080
Middlesex, Four Corners School		1,180
Middlesex, North Branch School		700
Middlesex, Station		560
Middlesex Village	B. M.	568
Middletown Springs		887
Miles Mountain, Concord		2,470
Miles Pond, Concord		1,016
Miller Pond, Strafford		1,320
Mill Village, Vershire		1,040
Milton, Arrowhead Mountain		940
Mill Village, Waterbury		700
Milton, Cobble Hill		840
Milton, Keeler's Hotel		300
Milton, Roods Pond		374
Milton, School Number 5	B. M.	324
Milton, School Number 12		200
Milton, Station		355.7
Milton Village		356
Milton Pond		834
Mitchel Hill, Sharon		900
Minister Hill, Sandgate		2,117
Missisquoi (East Richford)		540
Moffit Mountain, Sandgate		2,278
Molly Pond, Stowe		760
Mollys Pond, Cabot		1,620
Molly Stark Mountain, Huntington		2,940
Morrisville, Station	B. and M. R. R.	646
Morrisville Village	Aneroid, H. L. F.	610

Locality.	Authority.	Altitude.
Moscow, Stowe		640
Moscow, Near Trolley Station		672.3
Mount Abraham, Lincoln		4,052
Mount Clarke, Underhill		3,150
Mount Cleveland, Granville		3,200
Mount Ellen, Warren		4,135
Mount Ethan Allen, Duxbury		3,688
Mount Grant, Lincoln		3,661
Mount Holly		1,398
Mount Hunger, Barnard		2,360
Mount Ira Allen, Duxbury		3,506
Mount Mansfield, Chin, Underhill and Stowe		4,393
Mountain Glen Lodge, Duxbury		2,600
Mount Monadnock, Lemington		3,025
Mount Morrill, Strafford		1,702
Mount Mother Merrick, Sandgate		3,320
Mount Nevins, Brookfield		2,080
Mount Norris, Lowell		2,505
Mount Pleasant, Lincoln		1,800
Mount Prospect, Williamstown		2,040
Mount Roosevelt, Ripton		3,580
Mount Tabor		700
Mount Tom, Plymouth		2,160
Mount Wilson, Ripton		3,756
Mud Pond, Irasburg		1,200
Mud Pond, Leicester		585
Mud Pond, Charlestown		1,141
Mud Pond, Orwell		740
Mud Pond, Sharon		860
Mud Pond, Stamford		2,760
Mutton Hill, Charlotte		428
Monadnock Mountain, Lemington		3,025
Monastery Mountain, Hancock		3,222
Monkton, Ridge		598
Monkton Pond		491
Monkton Village	B. M.	533
Montague Hill, Bridgewater		2,500
Montgomery Center, Baptist Church	B. M.	533
Montgomery, South School	B. M.	719
Montgomery Village, Methodist Church		493
Montpelier, C. V. Station		520
Montpelier, Cutler School		820
Montpelier, Cutler Cemetery		1,004
Montpelier, Green Mount Cemetery (at river)	B. M.	522
Montpelier, Gallup Hill		1,258

Locality.	Authority.	Altitude.
Montpelier, Post Office	B. M.	546.5
Montpelier, Front of State House		540
Montpelier, School Number 7		1,312
Montpelier, School Number 8		1,210
Montpelier, School Number 10		1,160
Montpelier Junction		520
Montpelier Center		1,140
Moores Pond, Plymouth		1,320
Moosalamoo Mountain, Salisbury		2,659
Moosehorn Mountain, Wells		1,845
Moretown, Bridge, 350 feet south of Post Office		600.6
Moretown, Common		108
Moretown, Cox Brook School		840
Moretown, Number 5 School		568
Moretown, Number 9 School		1,200
Moretown Village		620
Moretown Gap		1,575
Morgan Mountain		1,640
Morrisville, Hotel	Aneroid, H. L. F.	667
Morrisville, Park		681.6
Nancy Hanks Peak, Warren		3,800
Nashville, Jericho Center		751
Neal Hill, Hartford		1,280
Neal Pond, Lunenburg		1,195
Nebraska Notch Road		1,760
Netop Mountain, Derby South Peak		1,600
Netop Mountain, Derby, North Peak		1,740
Netop Mountain, Dorset		3,120
Newark		N. S.
New Boston, Norwich		500
Newbury, Station		418
Newfane, Church		571
Newfane Hill		1,630
Newfane, Williamsville		540
New Haven, Brooksville		240
New Haven Junction		282
New Haven Mills		338
New Haven, Spring Grove		408
New Haven Village	B. M.	450
Newport Village	B. M.	454
Newport, Burlington School		893
Newport, Lake Road School		740
Newport, Federal Building		722.8
Newport, Main part of town		700
Newport, Wright School		1,387

Locality.	Authority.	Altitude.
Newport, Station		671
Newport Center, R. R. Station		777.4
Nickwacket Pond		....
Nickwacket Mountain, Chittenden		2,720
Nigger Pond, Westmore		1,825
Niggerhead Pond, Marshfield		N. S.
North Bennington		640
North Bridgewater		1,264
North Calais		N. S.
North Clarendon		680
North Chittenden		1,000
North Concord	St. J. and L. C. R. R.	1,091
North Derby		714
North Dorset		700
North Duxbury		378.5
Northeast Mountain, Wells		2,125
North Enosburg		400
North Fayston, Twenty-five feet south of School		926.7
North Fayston, East School		1,560
North Ferrisburg Village		163
North Hartland		383
North Hero, Bow Arrow Point		140
North Hero, Hotel		120
North Hero, Pelot Point		140
North Hyde Park	Aneroid	770
North Jay, School		1,000
North Landgrove		1,260
North Montpelier, Iron Bridge		670
North Orwell		573
North Pawlet		602
North Pomfret		800
North Pond, Marlboro		1,440
North Pownal		560
North Rupert		745
North Sheldon, Station		385.7
North Sheldon, School		376
North Sherburne		1,260
North Thetford, Station		395
North Thetford, Iron Bridge, south		399
North Troy, Hotel		610
North Troy, Station		603
North Tunbridge		640
North Underhill	C. V. R. R.	720
North Williston, Brick Mill east of Station		305
North Windham		N. S.

Locality.	Authority.	Altitude.
North Wolcott		N. S.
North East Mountain, Wells		2,125
Northboro, Thetford		N. S.
North Pond, Bristol		2,100
North Pond, Chittenden		2,320
North Pond, Marlboro		1,540
Northfield Falls		680
Northfield, Fair Grounds		740
Northfield, Harlow Bridge School		800
Northfield, Holton School		917
Northfield, Number 19 School		1,260
Northfield, University grounds		856
Northfield, Station		660
Norton Hill, Shaftsbury		1,920
Norton Mills, Station	G. T. R. R.	1,252
Norton Mills, International Boundary	White	1,250
Norwich, Bradley Hill		1,220
Norwich, Near corner Mechanic and Main Sts.		536
Norwich, Station		400
Notown, Stockbridge		1,300
Noyes Pond, Chittenden		2,320
Nulhegan, Station, post 157.9 miles from Montreal		923
Nulhegan, River crossing	G. T. R. R.	1,121
Oakland Station, 80 feet north of crossing		461.3
Oak Hill, Benson		900
Ohio Hill, Bridgewater		2,380
Old City, Strafford		1,260
Old Knob, Poultney		1,150
Old Sixty Hill, Granville		1,780
Olympus Mountain, Bethel		2,500
Orange		N. S.
Orcut Hill, Pawlet		1,460
Orleans, Reservoir		750
Orleans, Savings Bank		739.7
Orwell		385
Owls Head Mountain, Dorset		2,535
Owls Head, Richmond		1,160
Owls Head, Waterbury		1,600
Paine Mountain, Northfield		2,405
Panton Village		200
Paper Mill Village, Bennington		640
Parker Hill, Castleton		575
Passumpsic, Station, sill of waiting room	B. and M. R. R.	531
Patch Pond, Mount Holly		1,750

Locality.	Authority.	Altitude.
Pattern, Pawlet		860
Patterson Mountain, Vershire		2,321
Pawlet Mountain		1,800
Pawlet Village		680
Peabody Mountain, Weston		2,787
Peacham Corners	Aneroid	1,310
Peaked Mountain, Bakersfield		1,931.8
Pearl, Grand Isle		200
Pease Mountain, Charlotte		700
Pecks Pond, Barre		1,019
Pensioner Pond, Charlestown		1,141
Perch Pond, Benson		500
Perkinsville, Weathersfield		N. S.
Perry Hill, Waterbury		1,160
Peru Village		1,640
Petersburg Junction, Station	B. and M. R. R.	467
Peth, Braintree		N. S.
Phelps Falls, Troy		756
Philadelphia Peak, Rochester		3,168
Phillips Pond, Westfield		1,110
Philo Mountain, Charlotte		968
Pico Mountain, Sherburne		3,967
Pico Pond, Sherburne		2,220
Piermont, Bradford Station		430
Pine Hill, Addison		1,800
Pine Hill, Fairfield		1,300
Pine Hill, Middlebury		1,460
Pine Hill, Proctor		1,445
Pinnacle, Bridgewater		2,540
Pinnacle, Shoreham		655
Pinnacle, Stowe		2,740
Pinnacle, Warren		1,700
Pinnacle, Wells		1,940
Pinney Hollow, Plymouth		1,080
Pisgah Mountain, Westmore	Beers	3,800
Pittsfield, Brown School		1,063
Pittsfield, River School		810
Pittsfield Village		540
Pittsfield, White School		884
Pittsford Mills		540
Pittsford, Station		370
Pittsford Village		600
Pittsford, Whipple Hollow		600
Plainfield, Station	M. & W. R. R.	752
Pleasant Mountain, Lunenburg		800

Locality.	Authority.	Altitude.
Plymouth, Five Corners		1,340
Plymouth, Ponds		1,395
Plymouth, Union		1,217
Plymouth Village		1,420
Podunk, West Hartford		392
Pomfret Village		1,333
Pompanoosuc, Station		392
Pompanoosuc Village		400
Pompanoosuc, N. W. end of R. R. Bridge southwest		392
Pond Hill, Castleton		1,150
Pond Mountain, Vernon		1,190
Pond Mountain, Wells	South 360 North	1,518
Post Mills, Thetford		N. S.
Potter Pond, Irasburg		840
Poultney, Clark Hollow		920
Poultney, East		520
Poultney, Fennel Hollow		660
Poultney, South		560
Poultney, Station		430
Pownal Center, Church	B. M.	986
Pownal Center, a fourth of a mile south		1,095
Pownal, Methodist Church	B. M.	549
Pownal, Schoolhouse	B. M.	629
Pownal, Station		600
Pownal, Wright's Mill	B. M.	539
Preston Pond, Bolton		1,160
Preston Hill, Thetford		1,480
Prindle Corners, Charlotte		438
Pritchard Mountain, St. George		1,140
Proctor Lodge		2,540
Proctor, Church		560
Proctor, Hotel		480
Proctor, Marble Mills	B. M.	377
Proctor, Pine Hill		1,445
Proctor Hill, Mt. Holly		2,264
Proctorsville, Station	Rut. R. R.	928
Prospect Mountain	Woodford	2,690
Prospect Hill	Dummerston	1,174
Prospect Hill	Westford	1,046
Pulpit Mountain, Guilford		1,240
Pumpkin Hill	St. J. and L. C. R. R.	986
Purchase Hill, Thetford		2,544
Putnamville, Middlesex		640
Putney, East, Church		327

Locality.	Authority.	Altitude.
Putney, Station		260
Putney Village, at brook crossing		320
Queen City Park, Burlington		150
Quechee, Station		600
Quimby Mountain, Sharon		1,699
Ragged Hill, Bridgewater		2,080
Randolph, Station	C. V. R. R.	691
Randolph Center		N. S.
Ransomvale, Castleton		700
Rattlesnake Point, Salisbury		1,800
Rawsonville, Jamaica		1,070
Raymond Hill, Bridgewater		2,080
Ray Pond, Wilmington		1,840
Reading, Bailey Mills		1,077
Reading, Brown School		1,742
Reading, One mile east of Brown School	B. M.	1,375
Reading, Hill School		1,160
Reading Pond		1,760
Reading Village		1,067
Readsboro Falls		1,660
Readsboro, Heartwellville		1,800
Readsboro Village		1,203
Red Mountain, Arlington		2,960
Red Rock, Hinesburg		1,600
Red Rocks, Burlington		160
Revoir Hill, Coventry		800
Rhode Island Corners, Hinesburg		767
Rice Hill, Dover		2,947
Rice Hill, Highgate, North end		820
Rice Hill, Highgate, South end		760
Rice Mountain, Roxbury		3,060
Rices Mills, Thetford		640
Richardson Hill, Strafford		1,715
Richford, Guillmette Pond		760
Richford, Hardwood Hill		1,161
Richford, School Number 4		771
Richford, Station, C. P. R. R.		504
Richford, Station, C. V. R. R.		462
Richford Village, Town Hall front		476
Richmond Hill, Bridgewater		2,320
Richmond Pond		625
Richmond, Tower School		562
Richmond Station (Five hundred feet south)		318.5
Richmond, Universalist Church	B. M.	319
Richville, Shoreham		340

Locality.	Authority.	Altitude.
Ricker Mountain, Waterbury		3,401
Ried Hollow, Halifax		1,200
Ripton, Bridge over Creek	B. M.	1,017
Ripton, Fisher School		1,415
Ripton Village		1,000
Riverside, Jericho (Bridge over West River)		696
Riverton, Berlin, Station		602
Riverton, Berlin, One mile south of Station		670
Roach Pond, Hubbardton		537
Robbins Mountain, Bolton		2,080
Robinson Hill, Shrewsbury		2,779
Robinson, Rochester		1,004
Rochester, Branch School		914
Rochester, Corner School		1,085
Rochester, Jerusalem School		1,600
Rochester Mountain		2,952
Rochester, Randolph Gap		2,353
Rochester, West Hill School		1,720
Rochester Village		1,857
Rochester, Williams Talc Mine		2,000
Rock Hill, Pawlet		1,506
Rockingham	Rut. R. R.	357
Rockville, Starksboro		535
Roger Hill, Mt. Holly		1,640
Rogers Peak, Rochester		2,200
Roods Pond, Milton		376
Roods Pond, Williamstown		1,400
Roman Mountain, Goshen		3,020
Root Pond, Benson		380
Round Mountain, Chittenden		3,315
Round Hill, Irasburg		1,300
Round Hill, Shrewsbury		1,680
Round Mountain, Brattleboro		1,508
Round Mountain, Chittenden		3,315
Roundtop Mountain, Underhill		3,371
Rowell Hill, Norwich		1,200
Roxbury, Bull Run School		1,058
Roxbury, Cram Hill School		1,700
Roxbury Village	B. M.	1,007
Roxbury, Fish Hatchery		1,058
Roxbury, Flat		960
Royalton, Road Crossing one mile and a half N. W. Station		501.79
Royalton, Station (rails)		513
Rupert, Clark Hollow		940

Locality.	Authority.	Altitude.
Rupert, East		840
Rupert Mountain		1,860
Rupert, Station		700
Rupert Village		814
Russ Pond, Elmore		N. S.
Rutland, East St. and Jackson Ave.		600
Rutland, Evergreen Cemetery		540
Rutland, Killington Ave. and Stratton Road		820
Rutland, South Main, R. R. Crossing		545
Rutland, Post Office		600
Rutland, Station		560
Rutland, Woodstock Ave. and Broad St.		670
Ryegate, Station, B. and M. R. R.		464
Sable Mountain, Stockbridge		2,690
Sadagwa Pond, Whitingham		1,660
Saddle Pond, Waterville		N. S.
Sage Hill, Jamaica		2,140
St. Albans Bay	B. M.	108
St. Albans, Fuller School		180
St. Albans, French School		1,019
St. Albans, Lake and Main Streets		400
St. Albans, Smith and Congress Streets		600
St. Albans, Station	B. M.	385
St. Albans, Weeds Corners		560
St. Albans Hill, Georgia		900
St. Catherine Lake		477
St. Catherine Mountain, Poultney		1,227
St. George		500
St. Johnsbury Center	Aneroid	610
St. Johnsbury, Atheneum	Aneroid	660
St. Johnsbury, Court House	Aneroid	665
St. Johnsbury, Weather Bureau		711
Salem Hill, Derby		1,540
Salem Pond, Derby		963
Salisbury, Station		357
Salisbury Village		440
Salt Ash Mountain, Plymouth		3,278
Samsonville, Enosburg		440
Sandgate		800
Sargent Hill, Norwich		1,240
Sargent Hill, Pawlet		1,279
Sargent Pond, Coventry		700
Saxon Hill, Essex		820
Saxtons River Village		920
Scallop Mountain, Dorset		2,380

Locality.	Authority.	Altitude.
Scott Pond, Charlotte		260
Scrabble Hill, Duxbury		2,309
Scragg Mountain, Waitsfield		2,628
Searsburg Village		1,700
Seaver Hill		960
Seymour Lake, Morgan		1,279
Shaftsbury Center		1,100
Shaftsbury, South		737
Shaftsbury Village	B. M.	711
Shaker Mountain, Starksboro		1,920
Sharon, Abutment of R. R. Bridge		450
Sharon, Station		502.6
Shatterack Mountain, Jamaica		1,940
Shatterack Mountain, Rupert		2,376
Shatterack Hill, Derby		1,200
Shattuck Hill, Derby		1,200
Shaw Mountain, Benson		664
Shawville, Sheldon		390
Sheffield		N. S.
Shelburne Falls		206
Shelburne Pond		329
Shelburne, Station		160
Shelburne Village	B. M.	174
Sheldon Junction		330
Sheldon, North Sheldon School		440
Sheldon, Rice Hill Church		300
Sheldon, Rice Hill School		457
Sheldon Springs	B. M.	339
Sheldon Village	B. M.	374
Shellhouse Mountain, Ferrisburg		680
Sherburne Village		1,260
Sherman, Whitingham		1,100
Shoreham, Hotel		380
Shrewsbury, Cold River		1,500
Shrewsbury, North		1,760
Shrewsbury Peak		3,737
Shrewsbury Village		1,640
Silent Cliff, Hancock		2,460
Silver Lake, Barnard		1,305
Silver Lake, Georgia		783
Silver Lake, Leicester		1,240
Simonds Hill, Pawlet		1,240
Simonsville, Andover		N. S.
Single Hill, Wells		1,120
Sisson Hill, Shoreham		517

Locality.	Authority.	Altitude.
Skeels Corner, Swanton		320
Slack Hill, Plymouth		2,120
Slayton Pond, Montpelier		1,240
Smith Peak, Shrewsbury		3,226
Snake Mountain, Addison		1,271
Sodom, Shaftsbury		520
Sodom Pond, Adamant		1,036
Somerset Village		2,000
South Barre		800
South Dorset		980
South Duxbury		781
South Fairlee, Station		430.7
South Franklin, Station	B. and M. R. R.	373
Southgate Mountain, Bridgwater		1,720
South Halifax		850
South Hero Village		140
South Hero, Iodine Springs House		160
South Hill, Stockbridge		2,000
South Hinesburg	B. M.	434
South Lincoln, Three-fourths mile west of Village		1,249
South Lincoln Village		1,330
South Londonderry Village		980
South Lunenburg Village		1,180
South Newbury, a mile southwest near track		400
South Newbury, Station		407
South Newfane		680
South Newport		1,260
South Northfield Village		900
South Peacham	Aneroid	1,000
South Peak, Shrewsbury		3,226
South Pomfret, Library		736.5
South Pomfret Village	B. M.	738
South Poultney		700
South Richford		800
South Royalton, Station	C. V. R. R.	501
South Ryegate, Station	M. and W. R. R. R.	724
South Shaftsbury, Bridge	B. M.	711
South Shaftsbury, One mile south		788
South Shaftsbury, Town Hall	B. M.	754
South Starksboro		1,098
South Strafford		940
South Vernon Junction		240
South Vershire		1,550
South Walden	Aneroid	1,300
South Wallingford		580

Locality.	Authority.	Altitude.
South Wardsboro		1,000
South Whitingham		1,580
South Windham		N. S.
South Woodbury, Church	Aneroid	870
South Woodstock	B. M.	1,055
South Mountain, Bristol		2,387
Spanktown		590
Spaulding Hill, Poultney		1,620
Spoon Mountain, Middletown, South Peak		2,030
Springfield, Fellows Shop	A. J. Crosby	630
Springfield, Mansion Hill	A. J. Crosby	683
Springfield, Upper Main Street	A. J. Crosby	567
Springfield, Seminary Hill	A. J. Crosby	693
Spring Grove Camp Grounds		408
Spruce Mountain, Arlington		3,060
Spruce Knob, Poultney		2,320
Spruce Pond, Orwell		720
Spruce Top	Pawlet	1,378
Stacy Mountain, Wardsboro		1,935
Stamford Village, Methodist Parsonage	B. M.	1,131
Stamford Pond		2,520
Stannard		N. S.
Standing Pond, Sharon		1,380
Stark Mountain, Fayston		3,585
Starksboro, Gore School		1,132
Starksboro, Jerusalem School		1,300
Starksboro, Number 11 School		1,600
Starksboro Village		612
Starksboro, Rockville		535
Sterling Mountain	Guyot	3,700
Stevens Mills, Richford		540
Stiles Mountain, Sudbury		1,220
Stillwater Swamp, Barton		1,280
Stimson Mountain, Bolton		1,900
Stockbridge, Branch School	B. M.	750
Stockbridge, Notown		1,200
Stockbridge, Station	B. M.	733.9
Stockbridge, Sunny Brook School		963
Stockbridge Village		840
Stone Hill, Norwich		1,680
Stowe, Lower Village		640
Stowe, Luce Hill School		1,660
Stowe, North Hollow School		1,140
Stowe, Soldiers' Memorial Building		723
Stowe, South Hollow School		1,080

Locality.	Authority.	Altitude.
Stowe West Branch School		764
Stowe, Main Village	B. M.	.723
Stowe, Pinnacle		738
Strafford Village		960
Stratton Mountain		3,859
Stratton Pond		2,470
Stratton Village		1,860
Styles Peak, Peru		3,404
Sucker Pond, Stamford		2,240
Sudbury, Northeast corner of Church		572
Sugar Hill, Goshen		2,091
Sugar Hill, Derby		1,540.15
Sugar Loaf Mountain, Underhill		2,979
Sugar Loaf Mountain, Westfield		2,543
Sugar Loaf Mountain, Warren		2,120
Summit, Chittenden		732
Summit, Groton	W. R. R. R.	1,388
Summit, Mt. Holly		1,500
Summit, Siding	B. M.	924
Summit, Station		946
Summit, Summit	C. P. R. R.	1,377
Sunderland, Chiselville		760
Sunderland, Kelley Stand		2,160
Sunderland, Kansas		840
Sunderland, Lye Brook Meadows		2,600
Sunderland, McIntyre		2,060
Sunderland Village		649
Sunset Hill, Salisbury		925
Sunset Hill, Stowe		1,120
Sunset Lake, Benson		503
Sunset Lake, Brookfield		1,272
Swanton Junction, Station, R. R. Bridge over road		202.58
Swanton, School Number 3		416
Swanton, School Number 8		183
Swanton, Station, C. V.		155
Swanton, West Station		137
Swanton, Village Park		155
Swearing Hill, Sandgate		1,320
Tabor Mountain, Peru		3,584
Tabor Hill, Stowe		1,220
Tarbelleville, Mount Holly		1,540
Tadmer Hill, Pawlet		1,568
Taftsville, Woodstock	B. M.	668
Talcville, Rochester		800
Terrible Mountain, Andover		2,844

Locality.	Authority.	Altitude.
Texas Hill, Hinesburg		1,560
The Ball, Arlington		2,715
The Burning, Sunderland		2,607
The Island, Weston		1,220
The Ledge, Cornwall		380
Thresher Hill, Braintree		1,640
Thetford Center		600
Thetford, Campbell Corner		730
Thetford, Post Mills		720
Thetford, Rices Mills		580
Thetford, Station		408
Thetford, Union Village		520
Thistle Hill, Pomfret		2,000
Thompsons Point, Charlotte		200
Thompsons Point, Station		180
Thousand Acre Hill, Chittenden		2,400
Thunder Head, Hancock		1,240
Tice, Holland		1,140
Tillotsons Mills, Lowell		1,340
Tinmouth Pond		1,200
Tinmouth Mountain		2,847
Tinmouth Village		1,263
Toad Pond, Charlotte		1,146
Tom Mountain, Plymouth		2,040
Tom Mountain, Woodstock		1,360
Topsham		N. S.
Town Hill, Pawlet		1,319
Town Hill, Poultney		1,100
Townshend		N. S.
Troy, East Hill School		960
Troy, Hitchcock School		999
Troy, North Troy	B. M.	605
Troy, River Road School		640
Troy, West Road School		760
Troy Village, Brock's Store		764
Trumbull Mountain, Shaftsbury		1,600
Tug Mountain, Thetford		1,893
Tunbridge Village		640
Tunbridge, Whitney Hill		1,260
Tunbridge, Williams Hill		1,900
Twin Ponds, Brookfield		1,215
Turkey Hill, Northfield		2,000
Tyson, Plymouth		N. S.
Underhill Center		779
Underhill Flats, Station	C. V. R. R.	707

Locality.	Authority.	Altitude.
Underhill, Number 13 School		1,000
Underhill, Fork in road half a mile south of School 13		948
Union Village, Thetford		440
Upper Graniteville		1,500
Vail Ridge, Pomfret		1,440
Vergennes, Bridge over Otter Creek		140
Vergennes, Station	B. M.	203
Vergennes, Stevens House		235
Vernon Center		1,680
Vernon Center, Church		290
Vernon, Station		280
Vernon Village		270
Vershire Center		1,680
Vershire, Copperfield		940
Vershire, Mill Village		1,140
Victory		N. S.
Waitsfield, Common		1,073
Waitsfield, Gap		2,143
Waitsfield, South School		1,240
Waitsfield Village	B. M.	608.4
Waits River, Topsham		N. S.
Wolcott		690
Walker Pond, Newport		973
Walden, Station	St. J. and L. C. R. R.	1,656
Wallace Ledge, Castleton		1,060
Wallingford, East Station		1,220
Wallingford, Road		2,157
Wallingford, South		620
Wallingford Village		580
Wallispond, Canaan		N. S.
Walnut Hill, Danby		1,546
Wantastiquet Mountain, Weston		1,384
Wardsboro, Bucketville		1,100
Wardsboro, South		1,600
Wardsboro, West		1,260
Wardsboro Village		980
Warner Hill, Troy		1,180
Warner Pond, Troy		605
Warren, Near Post Office		893
Warren, Hotel		893
Warren, Lincoln Pass, near Long Trail		2,424.5
Warren, Number 5 School		2,498
Warren, Number 7 School		1,500
Warren, Robinson School		800
Warren, South Olive School		1,300

Locality.	Authority.	Altitude.
Washington, Double Top Mountain		1,720
Washington Village		N. S.
Waterbury, East School		700
Waterbury, Kneeland Flat		639
Waterbury, Little River School		500
Waterbury, Loomis Hill School		1,220
Waterbury, Perry School		1,020
Waterbury, Post Office		425.4
Waterbury, Station		425
Waterbury Center	B. M.	655
Waterford		N. S.
Waterville		N. S.
Websterville, Barre		1,313
Wells, Village		502
Wells, East		1,080
Wells River Pond, Groton	Beers,	1,900
Wells River, Hales Tavern	Aneroid	395
Wells River, Station	M. W. R. R. R.	435
Wells River, Top of bolt in Signal base 402	B. and M. R. R.	446.4
Wenlock, Station	G. T. R. R.	1,149
West Addison		100
West Barnet		N. S.
West Berkshire	B. M.	546
West Bolton	B. M.	991
West Bolton, Stone Bridge		1,020.7
West Brattleboro, Congregational Church	B. M.	443
West Bridgewater	B. M.	1,058
West Burke, Station	B. and M. R. R.	9,324
West Castleton		500
West Charleston	B. M.	1,023
West Charleston, Drug Store		1,022
West Charleston, South Hollow School		1,462
West Concord, Station	St. J. and L. C. R. R.	876
West Chesterfield, Church	B. M.	403
West Corinth		N. S.
West Cornwall		460
West Danville, Station	St. J. and L. C. R. R.	1,496
West Derby		700
West Dover, Church		1,714
West Dummerston, Church		391
West Enosburg, Ovitt's Store		439.9
West Enosburg, Station		462
West Fairlee Village		760
Westfield, Trumpet School		1,240

Locality.	Authority.	Altitude.
Westfield Village	B. M.	1,155
Westford, Bald Hill		1,240
Westford, Brookside School		510
Westford, Bowmans Corners		740
Westford Center	B. M.	467
Westford, King School		870
Westford Pond		790
West Glover		N. S.
West Hill, Worcester		2,280
West Halifax		1,180
West Hartford, Opposite Station		420
West Hartford, Fifty feet north of Station		420.5
West Haven		380
West Jamaica		1,540
West Lincoln, North end of Iron Bridge		890
West Marlboro		1,760
West Milton		114
Westminster, Station	B. and M. R. R.	256
Westmore, Hinton School		1,760
Westmore, Lake View School		1,320
Westmore, Long Pond		1,385
Westmore, Nigger Pond		1,825
Westmore, North Part		1,186
Westmore, South Part		1,200
West Newbury		N. S.
West Mountain, Shaftsbury		2,420
West Norwich		1,120
Weston Village		1,300
West Pawlet		480
West Rupert, Station		709
West Rupert Village		760
West Rutland, Station		500
West Salisbury	B. M.	420
West Swanton		108
West Topsham		N. S.
Westville, Groton		N. S.
West Townshend		N. S.
West Wardsboro		1,340
West Windsor, Ralph School		1,240
West Woodstock		713
Weybridge Center		420
Weybridge Village		160
Whetstone Bluff, Sunderland		2,200
Wheelock		N. S.
Whipple Hollow, Pittsford		600

Locality.	Authority.	Altitude.
Whitcomb Hill, Strafford		1,859
White Creek, Station		660
White Hill, Dover		2,702
White Hill, Hillsdale		1,713
Whites Hill, Wardsboro		2,702
White River Junction, Bridge over White River		340
White River Junction, Catholic Church	B. M.	367.5
White River Junction, Fairview Terrace		440
White River Junction, Second Terrace		500
White River Junction, Station		340
White Rocks Mountain, Goshen		3,307
White Rocks Mountain, Worcester		3,220
White Rocks, Wallingford		2,662
Whiting		391
Whitingham		1,600
Whitney Hill, Tunbridge		1,440
Wickopee Hill, Dummerston		1,650
Wilcox Hill, Benson		688
Wilcox Hill, Shrewsbury		2,072
Wilcox Peak, Pittsfield		2,921
Wilder, Station		408.7
Wilder, Library, Sill side door	B. M.	430
Willey Hill, Waterbury		1,200
Williams Hill, Tunbridge		1,940
Williamstown, Baptist Street School		1,475
Williamstown, Boyce School		1,100
Williamstown, Lynde School		1,085
Williamstown, South Hill School		1,400
Williamstown, School Number 13		1,666
Williamsville, Church	B. M.	560
Williamsville, Station		400
Williston, Methodist Church	B. M.	501
Williston, Top of Muddy Brook Hill		308
Willoughby Lake, Westmore		1,169
Willoughby Mountain	Beers	2,654
Willoughby Lake, Road at north end of Lake		1,191
Wilson Hill, Brandon		688
Wilmington, Baptist Church	B. M.	1,548
Wilmington Village		1,560
Winhall Village		1,200
Winhall, Bondville		1,200
Windham		N. S.
Windsor, Band Stand in Park	Aneroid	380
Windsor, Methodist Church		354
Windsor, Main St. and Depot Ave.	Aneroid	350

Locality.	Authority.	Altitude.
Windsor, Old Cemetery	Aneroid	360
Windsor, Station		325
Windsor, Track at Station	B. and M. R. R.	321
Winooski, North end of Bridge		136
Winooski, Station		200
Winooski, Brick School		240
Winooski, River below the Falls		107
Wolcott, Station	B. and M. R. R.	720
Wolcott, Town Hall	Aneroid	1,200
Woodbury		N. S.
Woodford, In front of Power House	B. M.	1,672
Woodford, Near Church	B. M.	2,215
Woodford Hollow, Camp Comfort		1,267
Woodford, Five miles east, top of hill		2,268
Woodlawn Mountain, Danby		3,072
Woodstock, Curtis Hollow School		1,166
Woodstock, Fletcher School		1,340
Woodstock, Pelton School		1,092
Woodstock Village		705
Woodstock, Walker School		1,700
Woodward Mountain, Bolton		2,700
Worcester, Hampshire Hill School		1,362
Worcester, Hunt School		765
Worcester, Minister Brook School		1,100
Worcester Ponds		1,067
Worcester Village, 100 feet north of Post Office	B. M.	779.6
Worcester, Wheeler School		1,280
Worcester Mountain		3,286
Worth Mountain, Hancock		3,500
Wrightsville, Montpelier		615
Yantz Hill, Richmond		1,060
Zion Hill, Hubbardton		1,229

THE GEOLOGY OF GRAND ISLE COUNTY.

G. H. PERKINS.

In several previous Reports the Geologist has discussed different phases of the above subject and in the present, while writing especially of the rock beds of the northern part of the county, he intends also to give a brief summary of what has been stated in the former Reports. The chief emphasis is here given to the northern part of the county because the southern part, particularly Grand Isle, has been treated with considerable detail already, more than any other part of the county.

As all Vermonters well know, Grand Isle County is made up of the largest island, which gives its name to the county, Grand Isle, and also of the islands of North Hero and Isle La Motte and the large peninsula of Alburg, which projects from the Canadian border south for nearly twelve miles.

In the Third Report of this series, pages 102-173, Grand Isle, or, as often called, South Hero, is the only part of this area which is described. This account was published in 1902 and was intended to be introductory to a later and more intensive study of the geology of the island. After a somewhat general account of the geological features of the region, the special formations, especially along the west shore, where they are finely exposed, are separately discussed as to general features, but there is only very meager mention of the contained fossils, except in case of one or two conspicuous groups. The very numerous dikes which appear along the shores, over forty in number, are noticed. Nowhere in Vermont are dikes as numerous as on Grand Isle and they are specially considered in a following article by Dr. Hervey W. Shimer.

In the succeeding Report, Fourth, 1904, the study of the region is further carried on. In this discussion of the island rocks all parts of the county are taken up and more account is made of the fossils found, but for a special study of these the reader is referred to Dr. Rudolph Ruedemann's report, which is to be found on page 90 of the Twelfth Report, and his second list immediately following this article.

It may be of interest to geologists to know that the following beds are exposed in the area of this county:

Upper Trenton, found abundantly in all parts of the county.
Lower Trenton, found on Grand Isle and Isle La Motte.

Black River, found on Grand Isle in considerable amount, mostly though not wholly, in the western part, and at one locality in Isle La Motte.

Chazy, found on Grand Isle in the western part and Isle La Motte in the southern part.

Beekmantown, found in small exposures on the southwestern part, and much more on the southern part of Isle La Motte about the "Head."

As the beds exposed on Grand Isle have been more or less fully discussed in the previous articles named, they will be passed here with less attention.

As will be seen by reference to the Third Report, the rocks of Grand Isle are largely Upper Trenton shales, in color, generally black, though sometimes gray. On the west shore, however, different members of the Chazy appear in three not large areas. These can generally be studied to best advantage on the shore of Lake Champlain.

In the Fourth Report, page 103, there is a colored map of Grand Isle, from which one can readily understand the distribution of such formations as are to be seen on the island.

The account of the geology of Grand Isle County which is given in the Fourth Report is little more than a brief summary of the beds found, but it covers a wider range than that given in the Third Report.

In the Tenth Report the geology of this region is again taken up and at page 212 is begun a brief account of the location and character of the formations of this county. There are also two colored geological maps which together cover most of this area.

The Trenton beds of Grand Isle are more fully studied in the Twelfth Report, page 77, and here more attention is given to the fossils found, especially as this is followed by a list of these by Dr. Rudolph Ruedemann.

Anyone consulting these articles should know that what is called Utica in previous Reports is in the Twelfth and after, called Upper Trenton, as here and elsewhere, it has been seen that the shale, which had been regarded as identical with the New York Utica was continuous with the typical Trenton limestone and that there was no line of demarcation between them.

All of the above studies are fully illustrated by plates showing characteristic outcrops of the beds considered.

After several interruptions, it was possible to investigate more fully than had been done the portion of Grand Isle County north of that which had been hitherto examined: North Hero, Alburg and Isle La Motte.

C. E. Gordon, one of the staff of the Vermont Survey, has also examined the outcrops found on these islands and, beginning at page 114 of the Twelfth Report, is his article on the "Geology of Western Vermont," which includes (pages 247-256) Grand Isle County.

Passing north from Grand Isle one comes to North Hero.

NORTH HERO.

The only beds found on this island are those of the Upper Trenton and they are very much like those seen over the northern part of Grand Isle. Though for the most part the rocks of this island do not yield any distinct fossils, yet there are a few localities much richer than similar beds on the southern island.

At Hazen Point, and some rods north on the west shore and Hibbard Point on the east shore, fossils may be found, but there are only a few species as Triarthrus, a few Graptolites, etc. (see Ruedemann's list following). The Graptolites seem to be more abundant and more widely distributed than other fossils in these rocks.

In passing it may be noticed that the surface of North Hero is low and, except along the shores, more or less covered by drift. Nowhere is the land more than sixty feet above the lake and in only a few places as much as this. Because of the soft and friable nature of most of its rock, the shores of this island are very irregular and greatly eroded by the waves of the lake.

The change from lower rock easily broken by the hammer to that higher up, almost or quite to the surface, is very gradual and in many places the eye cannot find any division. The strata have in most places been very little disturbed and the upper clays, formed by the decomposed shale, though soft and easily shovelled, plainly show the original layers. Still in a few places there is considerable upheaval and the entire thickness, which has not been carefully measured, must be several hundred feet. The outcrops of the shale on North Hero are taken up in some detail in the Fourth Report, pages 109-146.

ALBURG.

The peninsula, Alburg, extends south from the Canadian border nearly twelve miles. Evidently, Alburg, Isla Motte and North Hero were formerly connected and the Upper Trenton was the surface rock which has been washed out by the lake through the Alburg Passage, between Alburg and North Hero and the La Motte Passage between it and Isle La Motte, both being narrow as the maps show, and nowhere very deep.

Over the whole of the above area the only rock found is the Upper Trenton shale, which, as everywhere in this region, is usually very destitute of fossils. There are, so far as I know, only two localities where it is worth while to search. At Coon Point at the southwest end, and East Alburg near the Canada line a few species, notably *Triarthrus becki*, Green, are found. Indeed, I have found nowhere else such an abundance of this trilobite as at Coon Point. Here this trilobite is found of different sizes and entire specimens can readily be obtained.

At Coon Point there is considerable disturbance of the beds, though the dip is nowhere more than thirty degrees and usually less. The shale is more heavily bedded than elsewhere and the cliffs on the shore may be forty feet high. Rarely, other Upper Trenton species are found here, but the main content of this shale

ISLE LA MOTTE.

Apparently this island has had a somewhat more varied history than is indicated by the rocks of the other parts of this county. Still it is more probable that when the whole region was one continuous body of land, the whole was under the same conditions and that whatever seeming differences we now find exist because of greater erosion in some places than others by which some, once existing formations, have been so completely removed that no trace remains. Indeed, though the lower formations, as Beekmantown and Chazy, are much more in evidence than on Grand Isle, they all appear, more or less on that island, although not at all on Alburg and North Hero as has been shown above.

To the field geologist, Isle La Motte offers much greater inducement for detailed investigation than any other part of the area considered. Especially is this true of the southern part of the island.

Geologically, the island is two, a northern, where only Trenton beds are to be found, and a southern of about equal size, where there are no Trenton beds, but, besides a very little Black River in one place, all is Chazy except at the most southern point, the "Head" where the Beekmantown is conspicuous, as also on the nearby Cloak Island. These two parts are separated by a swamp which runs across Isle LaMotte from east to west, which in driest times is only a little above the level of the lake.

In present evidences of glaciation this island by much exceeds the others, though there is no reason to suppose that originally it was treated differently from the rest, but only that the indications of former glaciation have not been so completely removed, as indicated above. Now about half of the northern part of this island is covered by drift to a depth of from a few inches to twenty feet, as shown by wells which reach down to the limestone.

About the north end the shore is thickly strewn with boulders, mainly of Canadian rocks, but local material is also found and some of this latter is very little worn and evidently has been transported not more than very short distances. There are also great piles of smaller boulders which have been picked from land that was to be cultivated.

Though glacial clays are most common as covering material, there is here and there considerable sand mixed with the clay. Small, more or less circular glacial pools are common in this part of the island and several interesting sea beaches are found in the western side of the northern part. These all extend north and south and often contain shells, sometimes abundantly, of *Macoma, Mytillus* and *Saxicava*. All are within a half mile of the west shore. One is eighty feet above the present water of the lake. Although much of the surface is covered as indicated, there is no reason to doubt that it is, in that part of the island north of the swamp, everywhere underlaid by Trenton limestone.

For the most part the Trenton beds are not greatly disturbed, though everywhere somewhat, and on the northeast there is an uplift, the highest point on the island, that reaches a hundred and twenty feet above the lake. This is higher than any land elsewhere in the county except at the southern point of the island, the "Head," where the Chazy rises to a hundred and forty feet. Although I have spent several days in investigating these Trenton beds, there should be more work done on them and I am sure that intensive study would be rewarded.

Dr. Ruedemann has examined the fossils found and to his list the reader is referred on following pages.

As Dr. Ruedemann's list shows, there are various beds exposed from the "Glens Falls" limestone at the bottom to the upper part of the "Canajoharie." Starting on the south, just north of the swamp, the Trenton limestone appears on both sides of the main highway, north to Cooper Point. From Cooper Point along the shore of the lake and for a greater or lesser distance west on the mainland, cliffs are seen, though nowhere very high. There are on the shore, three exposures, interrupted by short exposures of Upper Trenton shale.

Cooper Point, which is forty feet high, is composed of the common, compact limestone. The rock is sometimes quite fossiliferous, sometimes very barren. At this place there has been some faulting and the usual black limestone is replaced by a heavy grey bed, which has been lifted and pushed forward over the beds beneath. Numerous calcite veins in this locality are evidence of compression and disturbance. After passing several hundred feet south on the shore, a narrow strip of the black, shaly Upper Trenton extends for more than a mile. Evidently, these beds are the western edge of those which cover the whole of Alburg. Beyond this comes a small bay, the shore of which is strewn with boulders. Passing this bay, the more compact limestone comes to the surface for about two hundred feet, when it is replaced by a shingly beach south of which there is a fault and the Upper Trenton forms the shore, continuing for seven hundred feet on the shore and, back from the lake, rising in a cliff six or eight feet high, comes the lower limestone, like that north, for three hundred feet. For a short distance between the upper and lower beds the rock has been carried out.

South of the limestone there is the only outcrop of the Black River on the island.

After passing the swamp and going a little south of Jordan Point, the last of the upper shale is found. Here it forms the shore for four hundred and fifty feet and is greatly disturbed.

A word as to the little exposure of Black River. This is found not far north of the marsh on the east shore. It is not far from a hundred and fifty rods long and in the old quarry. Hill's Quarry, about twenty-five feet are shown. There are several beds of varying thickness and solidity. From the more compact upper layers a considerable quantity of stone, which is seen in a number of the older buildings, has been taken. Much of the stone has the familiar smooth jointing and very fine grain common in the Black River and affords very sparingly the more common characteristic fossils.

As has been stated above, the Chazy is well seen over nearly the whole southern part of Isle La Motte. The rocks of the Chazy have been so fully discussed in former Reports, especially in the Fourth, that little space will be given to it here. The paleontology of these beds needs much investigation and, I am sure, that any one who should carefully study them would be amply rewarded.

Brainerd and Seely spent considerable time on the stratigraphy of these rocks and many of the results of their work are given in the Fourth Report, also description of several species of *Stromatoceria* by Professor Seely and several plates.

In the Seventh Report Professor P. E. Raymond describes a number of the trilobites found in the Chazy beds of Isle La Motte and a few from localities in New York near Lake Champlain, pages 213-248, Plates XXXII-XXXIX. Some very interesting Cephalopods found in these same beds are described and figured by Doctor Ruedemann, Bulletin 90, New York State Museum.

The Chazy rocks of Isle La Motte are very varied, but are all more or less pure limestone, often very pure, often less so, and mixed with sandy material

At the "Head" there are very fine examples of cross-bedding, as some of the plates clearly show. Some of the beds are much disturbed, many very little. Anyone wishing a detailed account of these variable and often very different beds is referred to the Fourth Report.

Nowhere does the surface of the island rise to great elevation, but at the Head the rock masses reach a hundred and fifty feet above the lake.

CLOAK ISLAND.

Cloak Island is a small island of a few acres southeast of the larger island, about fifty rods from it. It is mainly a mass of Chazy rock, lower and middle, greatly disturbed and a fault crosses the southwestern portion. Some of the beds of Middle Chazy are brecciated like some of those on the main island. On the southwest of this island are some twelve feet of silicious beds which are probably Beekmantown.

As stated above, Dr. Ruedemann has studied the fossils of this region and has furnished the following list.

It should be remembered that the rocks called Utica in former Reports are, after the Twelfth, called Upper Trenton.

ORDOVICIAN FOSSILS COLLECTED BY PROF. G. H. PERKINS IN 1921.

LARRABEE POINT. Black shale.
Climacograptus strictus Ruedemann ms.
Diplograptus (Mesogr.) *macer* Ruedemann.

NORTH HERO. Black shale.
Glossograptus quadrimucronatus (Hall).
Climacograptus typicalis Hall (large) cc.
Geisonoceras cf. *tenuistriatum* (Hall).
Triarthrus becki Green.
Echinognathus? sp. (spine).

SOUTH HERO. Black shale.
Lingula cf. *curta* Hall.

ALBURG. Black shale (includes "Coon Point").
Triarthrus becki Green.

The collection from the black shale at Larrabee Point indicates Canajoharie age. Those from North Hero and Alburg point to the "Stony Point" shale of the former Report by the combination of *Glossograptus quadrimucronatus* and *Climacograptus typicalis* with *Triarthrus becki* Green. This horizon is of later Trenton age and corresponds to the uppermost Canajoharie shale.

SOUTH HERO. Bluish-black to dark gray limestone.

ECHINODERMA: Crinoid joints.

BRYOZOA.
Cheirocrinus cf. anatiformis (Hall), plates.
Prosopora simulatrix orientalis Ulrich.
Eridotrypa aedilis (Eichwald).

BRACHIOPODA.
Rafinesquina alternata (Emmons).
Dalmanella rogata Sardeson.

MOLLUSCA.
Ambonychia sp. cf. *orbicularis* (Emmons).
Vanuxemia sp.
Ctenodonta levata (Hall).

CRUSTACEA (Trilobita).
Cryptolithus tesselatus Green.
Calymmene senaria Conrad.
Ceraurus pleurexanthemus Green.

ISLE LA MOTTE. Bluish-black limestone and gray limestone. The bluish-black limestone contains:

BRYOZOA.
Pachydictya acuta (Hall).
Eridotrypa aedilis (Eichwald).
Prasopora simulatrix orientalis Ulrich.

BRACHIOPODA.
Lingula quadrata Hall.
Orbiculoidea lamellosa Hall.
Trematis terminalis Emmons.
Dalmanella rogata Sardeson.
Rafinesquina alternata (Emmons).
Strophomena incurvata Shepard (*Leptaena filistriata* Hall).
Plectambonites cf. *punctostriatus* Mather.
Platystrophia amoena McEwan.
Parastrophia hemiplicata (Hall).

MOLLUSCA.

PELECYPODA.
Ambonychia orbicularis (Emmons).
Modiolopsis sp.
Orthodesma sp.
Ctenodonta cf. *nasuta* (Hall).

GASTROPODA.
Sinuites cancellatus (Hall).
Bucania punctifrons (Emmons).
Holopea symmetrica Hall.

CEPHALOPODA.
Orthoceras amplicameratum Hall.
Geisonoceras tenuitextum (Hall).

CRUSTACEA.

TRILOBITA.
Cryptolithus tesselatus Green.
Isotelus gigas Dekay (cranidium).
Ceraurus pleurexanthemus Green.
Calymmene senaria Conrad.

The gray limestone slabs contain only: *Dalmanella rogata* and *Isotelus gigas*.

It appears from these lists that the Trenton limestone of Isle La Motte, like that of Grand Isle, for the greater part belongs to the bluish-black, somewhat shaly lowest division which is characterized by abundant *Cryptolithus tesselatus* and *Parastrophia hemiplicata* and known as Glens Falls limestone. The beds of the dark limestone, on Isle La Motte and South Hero, that have afforded the large specimens of *Prasopora simulatrix orientalis*, the characteristic fossil of the Prasopora beds of the Middle Trenton, probably belong to that higher horizon.

A comparison of the faunules from the black shales of Alburg and North Hero, with that from Larrabee Point confirms the conclusion set forth in a former Report that the black shales of the northern Champlain basin belong mainly to the "Stony Point" shale, a higher horizon of the Canajoharie shale, and the black shales of the southern region, as notably those along the Panton shore in Vermont and from the neighborhood of Ticonderoga and Willsboro Point on the New York side of the lake, are typical representatives of the Canajoharie shale, belonging to its lower division.

Most of the exposures of Trenton limestone in the Champlain basin are those of the lowest division or Glens Falls limestone. In the northern part of the basin also the Middle Trenton limestone appears below the black shale and is accompanied by a corresponding disappearance of the Lower Canajoharie shale which it replaces.

THE OLDEST CORAL REEF.

PERCY E. RAYMOND,
Harvard University.

It may be somewhat a surprise to those having a general knowledge of the Geology of New England to learn that the world's oldest coral reef lies within her confines. A narrow strip of Ordovician strata on the western border of Vermont escaped the metamorphism which so profoundly affected most of the rocks of the region, and in outcrops of this belt are found the oldest true corals. The reef in question is on Isle La Motte, about 40 miles northwest of Burlington, Vermont, and 5 miles east of Chazy, New York. The horizon is at the top of the Lower Chazy.

The outcrop is in pastures a quarter of a mile southeast of the extensive Goodsell quarries. The bare rock rises somewhat above the surrounding land, which is covered with turf, and in places, with cedars. The best exposure is roughly rectangular, about 700 feet long and 200 feet wide, but the reef can be traced for nearly half a mile toward the south. The surface has been planed off by glacial action, and somewhat modified by subsequent solution. The maximum relief is about 7 feet, and the corals are most abundant in the highest part. No section through the reef was found, but in places the nature of the rock for a depth of two or three feet could be observed along the enlarged joints. The surface, a diagram of a part of which is shown in plan in figure 1, shows numerous patches of corals grouped in irregularly oval areas separated from each other by dark gray rock made up of calcareous sand, and columnals of various pelmatozoans (crinoids, cystids, and Blastoidocrinus). These patches are often wholly or partly engirdled by areas of a rock which weathers to a rusty yellow, and which contains great numbers of Stromatoceria and Bryozoa. The individual heads of coral, an undescribed form to be known as Lamottia, are mostly white, and from 6 inches to 1 foot in diameter. Many are, however, smaller although one specimen over 18 inches in diameter was collected. In places individuals are grown together to make masses over 3 feet across, and in a single patch about 12 feet in diameter there are over 100 heads which are so close together that they

cover practically the whole surface. There are several areas of this sort.

The material in the areas between the patches of coral has a coarsely crystalline appearance, due chiefly to the pelmatozoan columnals in it, and contains great numbers of trepostomatous bryozoans and some brachiopods. In places individual coralla occur in this matrix.

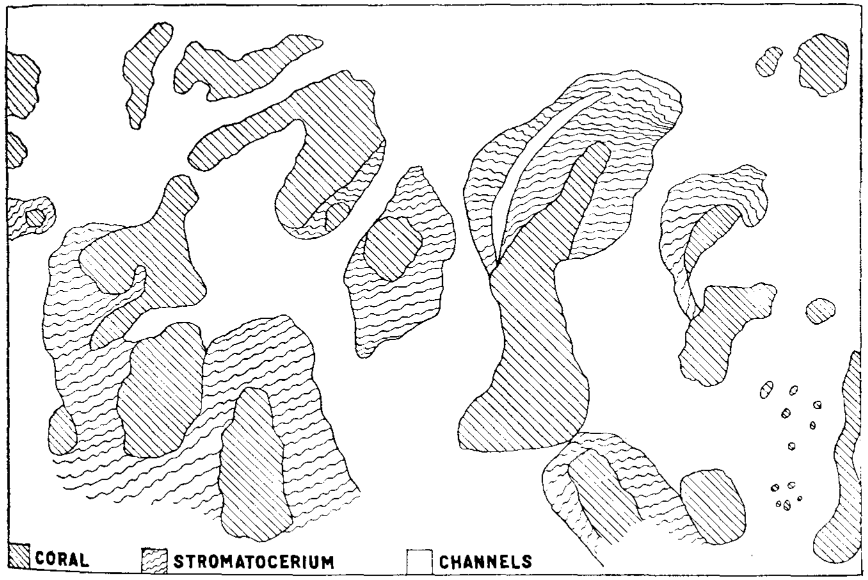


FIGURE 1. Diagram showing a plan of a portion 120 feet long and 80 feet wide of the Chazyan reef. The irregular patches diagonally lined are made up chiefly of corals, and the portions in wavy lines are masses of the hydrocoralline, Stromatocerium. The channels between the patches of organisms are left blank. Scale, 1 inch equals 26.6 feet.

In the figure presented here, the patches made up chiefly of coral are indicated by diagonal lines, the engirdling masses of Stromatocerium and bryozoans by wavy ones, and the areas filled with the dark, coarsely grained rock are left blank. Although satisfactory cross-sections are absent, it would appear that the corals grew up in mounds from the sea bottom, the Stromatoceria and bryozoa grew about them, and the other areas, now sand-filled, were probably open channels. If such were the case, conditions were then very similar indeed to those on a modern reef. That the growth was within the limits of strong wave action is shown conclusively by the fragmentary condition of the remains of the echinoderms, and by the occurence of the isolated heads of coral in the channels.

There seems to be some difference of opinion as to what may be called a true coral reef, and some might claim that it could not be shown that the structure described above really was one.

A reef, in a geographical sense, is defined by the Century Dictionary as: "1, a low narrow ridge of rocks, rising ordinarily but a few feet above the water," or, "2, any extensive elevation at the bottom of the sea." That the structure just described was an extensive elevation at the bottom of the sea may be deduced from the arrangement of the materials of which it is composed. It would, therefore, be a reef in accordance with at least one common usage of the word. Vaughan, in a recent paper[1] has stated that a reef should have predominance of corals among the organisms growing upon it, in order to be classed as a coral reef. This particular case seems to fulfill this requirement.

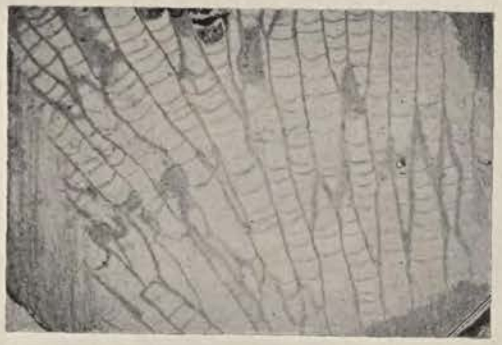
Daly, in a recent article in the *American Journal of Science* (August, 1919, p. 173) has insisted upon the ability of the structure to withstand the force of the breakers as an integral part of the definition of a coral reef. Although it would seem that the mere fact of the presence of reefs of corals in ancient strata was *prima facie* evidence that they had withstood the breakers, yet they may present other evidence of having successfully resisted the force of the waves. In the present case, the elongation of the masses of coral, all in the same general direction, the fragmental nature of the material filling the channels between the areas of coral, and the isolated heads of coral in the channels show that this structure was formed within the zone of vigorous wave action, and probably near the surface. The long axes of the patches point northeast and southwest, and since the Stromatocerium is more dense on the southeastern side it might be argued that the principal attack came from that direction, for the Stromatocerium, forming dense mats, probably performed the protective function of Lithothamnion at the present day.

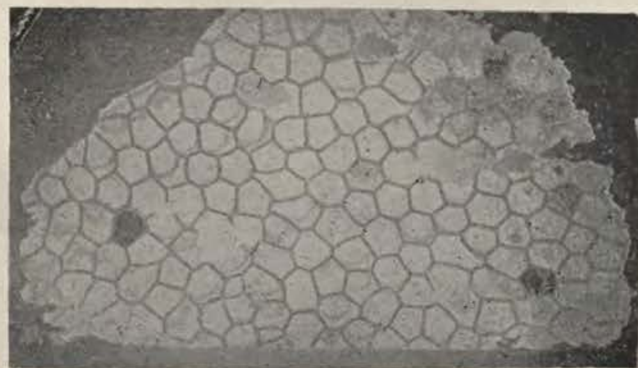
The Goodsell quarries on Isle La Motte exhibit extremely well the reefs of Stromatocerium so characteristic of the Middle and the lower part of the Upper Chazy. In them, one finds excellent examples of fragments of Stromatocerium which have been torn from the parent mass and battered about until they have become rounded boulders.

It is not claimed that this ancient coral reef is either an atoll, a barrier, or a fringing reef. It is not, therefore, necessary to show its relation to any land. It is, however, maintained that it was a coral reef, in the sense that it was a mass of coral growing above the general surface of the surrounding floor of the sea, and projecting up relatively near the surface. The reef had a length of at least half a mile, probably more, and an unknown width and thickness. The latter was probably comparatively small, perhaps not more than 12 or 15 feet.

[1] Bulletin U. S. Nat. Mus., 103, 1919.

PLATE I.





Chazy coral, *Lamottia heroensis*, Isle La Motte.

Grabau[1] has cited as examples of ancient coral reefs the masses of Archaeocyathidae found in the Lower Cambrian of Labrador, Newfoundland, California, Nevada, Sardinia, and northern Siberia. The Archaeocyathidae, although they grew in reef-like masses, are not sufficiently like true corals to be placed in any modern order and many do not consider them to be corals. He also cites the pre-Cambrian Atikokania as a possible builder of coral reefs. The specimens to which this name was given are of such doubtful nature that they have more recently been considered as possible remains of Algae, or even of inorganic origin.

Columnaria is often an important constituent of reef-like aggregates in the Black River (Middle) and Richmond (Upper Ordovician), but seldom grows in sufficient luxuriance to make dome or ridge-like reefs. An excellent example of such an assemblage may, however, be seen just south of the Trombley Bay Cemetery near the shore of Lake Champlain east of Chazy, New York. At this locality *Columnaria halli*, various calcareous Algae, and *Stromatocerium rugosum* make up almost the entire mass of one of the layers of the Black River.

The coral which makes up the major portion of the reef on Isle La Motte is like Favosites in habit, but lacks both septal spines and mural pores. Such corals have by some been referred to Fletcheria. Thus Lambe (Contributions to Canadian Palaeontology, 4, 1899, pt. 1, p. 48) referred to that genus the *Columnaria incerta* Billings which occurs on the Mingan Islands. Among the specimens which Lambe identified as *Columnaria incerta* were some (see Lambe's pl. 1, fig. 9) with polygomal corallites like the one in question, though the greater part of the specimens showed corallites which were circular in section and not quite in contact with one another.

The genus Fletcheria was based by Milne-Edwards and Haime (*Mon. des polypiers foss. des terr. palaeozoiques,* Paris, 1851, p. 300, pl. 14, fig. 5) upon their species *F. tubifera,* a coral from the Silurian of Gotland. Their description emphasizes the calicinal budding, which is well shown in their figure, whereas the lack of lateral connections between the tubes, the rudimentary septa, and horizontal tabulae are of course secondary matters, particularly if the corallites became pressed together in a Favosites-like habit.

The specimens from Isle La Motte show lateral instead of calicinal gemmation, and as no described genus has the combination of characteristics found in them, it becomes necessary to make a new one for their reception.

Sub-Order Tabulata Milne-Edwards and Haime.

Family Favositidae Milne-Edwards and Haime.

[1] Principles of Stratigraphy, p. 417, 1913.

GENUS LAMOTTIA nov.

Corallum massive, generally subglobose. Corallites prismatic, pentagonal or hexagonal, usually irregular, with one or more walls curved. Septa entirely absent, and neither septal spines nor squamulae present. Mural pores absent. Tabulae numerous, concave, seldom horizontal. Gemmation lateral. Type, *Lamottia heroënsis sp. nov.* Plate I.

LAMOTTIA HEROENSIS sp. nov.

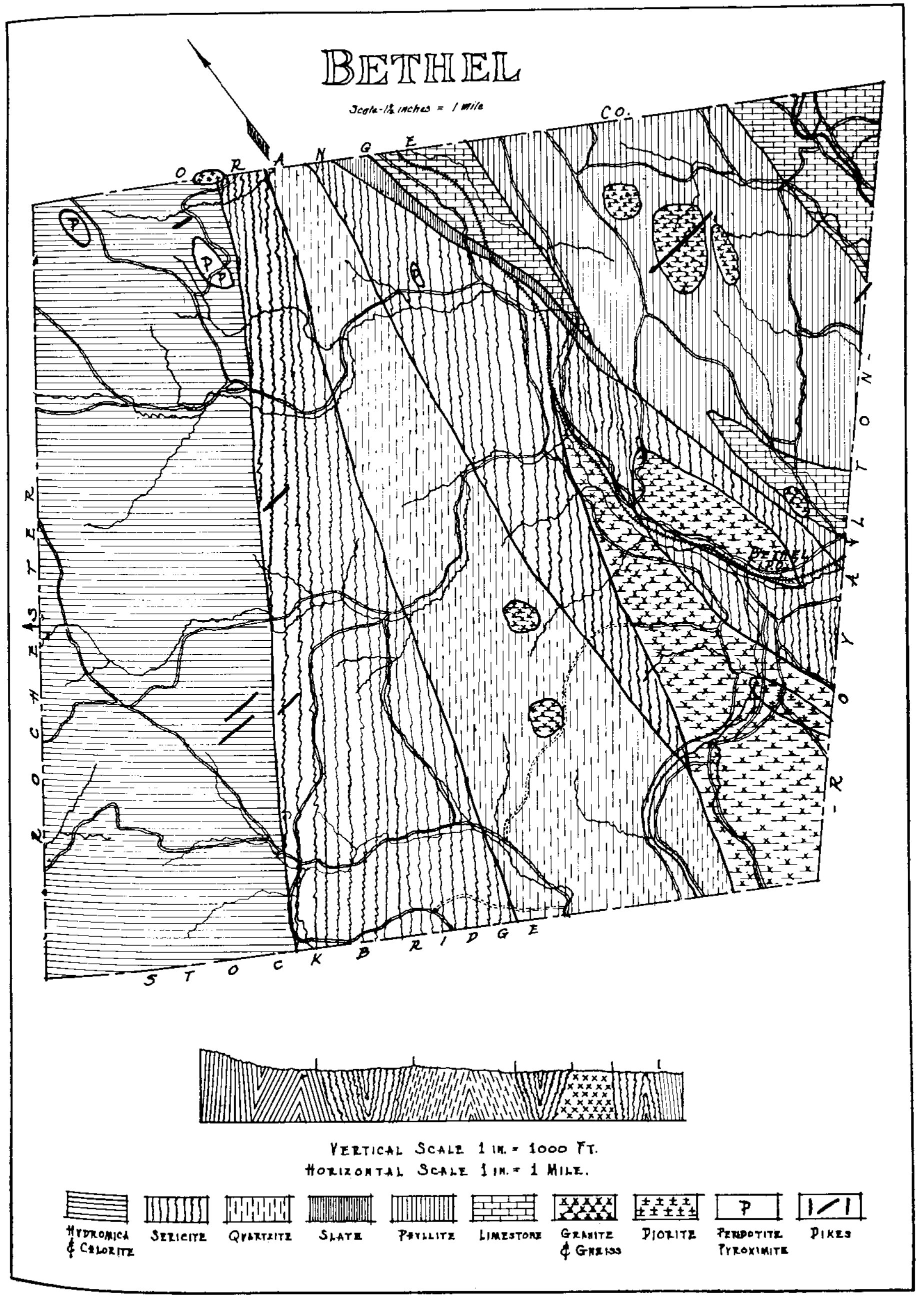
Corallum from 25 to about 600 mm. in diameter, somewhat irregular in shape. Corallites small, averaging about 1 mm. in diameter, and in thin section show a somewhat definite arrangement, one hexagonal corallite with convex sides being surrounded by six pentagonal ones. This arrangement of the cells does not extend over the whole surface, but there are many such groups, which give a rather distinctive appearance to the sections.

The tabulae are all concave with a rather deep median depression, so that sections across the center of the corallite show a rather abrupt deflection in that region. The tabulae are not equally spaced, but appear to average about seven in four mm. The walls of the corallites are usually poorly preserved, but in a part of one section the structure shows definitely that the walls of the adjacent prisms are not amalgamated, so that in this respect the condition is the same as in Favosites.

Newly budded corallites expand very rapidly to their maximum diameter, and gemmation appears to take place rather irregularly.

Horizon and locality. This species is rather common in the upper part of the Lower Chazy on the brow of the hill back of the house of Mr. Hall, 2 miles southwest of the station at South Hero, Vt., where the holotype, a small corallum, was collected. The specimens in the reef on Isle La Motte are all relatively large, but appear to belong to the species found at South Hero. The type was not selected from among the former because the preservation is not quite so perfect. A third locality for the same coral is in an old quarry near the station at Hotel Champlain, south of Plattsburgh, New York. Specimens are preserved in the Museum of the Boston Society of Natural History and the Museum of Comparative Zoology at Harvard College.

PLATE II.



Geological map of Bethel.

THE TERRANES OF BETHEL, VERMONT.

CHARLES H. RICHARDSON,

Syracuse University, Syracuse, N. Y.

INTRODUCTION.

The report upon the Terranes of Bethel, Vermont, is of necessity brief. It is one of progress in the solution of the many intricate problems dealing with the highly metamorphosed sediments and their associated intrusives in the eastern half of the State. Its purpose is to present in concise form the results of new field work and new petrographic study of the closely folded and intruded rocks of Bethel, Vermont, and to draw therefrom certain conclusions as to their origin, stratigraphic relation, mineralogical composition, and age.

The Township of Bethel is situated a few miles south of the central part of the State. It is also a little east of the central meridian traversing the State. It is 40 miles south of Montpelier, the State capital, and 25 miles northwest of White River Junction, which is situated on the eastern border at the confluence of the White and Connecticut Rivers. It is bounded on the northeast by Randolph, on the southeast by Royalton, on the southwest by Stockbridge, and on the northwest by Rochester. It is, furthermore, in the northern tier of towns in Windsor County and near the northwest corner. The village of Bethel, which is in the eastern part of the township, is approximately located by north latitude 43 degrees and 52 minutes, and west longitude 72 degrees and 37 minutes. There are four reasons for the selection of Bethel for field work: (1) It lies to the southeast of Randolph, whose geology and petrography have already been published in the Biennial Report of the State Geologist for 1921-1922. It makes the work continuous in a southeasterly direction in the eastern half of the State. (2) It falls in the line of the erosional unconformity between the Ordovician and the pre-Ordovician formations on the eastern side of the Green Mountains. (3) The presence of both acid and basic intrusives, whose mineral composition has never been published. (4) The fact that no detailed field or petrographic work has ever been done upon either the sedimentaries or their associated intrusives.

The author traversed the eastern part of this area in the summer of 1895. During a part of the summers of 1923 and

1924 a detailed study of the geology and mineralogy of the township was made. Also, T. N. Dale of the U. S. Geological Survey visited the granite area on Christian Hill in 1907, and his results were published in the Biennial Report of the State Geologist for 1909-1910.

The field relations of the different terranes in Bethel are intricate, and often difficult to determine. The township as a unit is hilly, glaciated, and in part densely wooded. As a result of these conditions, actual contacts between the different formations are seldom found.

An areal map showing roughly the distribution of the different terranes in Bethel accompanies this report as Plate I. A cross-section is drawn practically at right angles across the strike of the various formations and through the center of the township. It is regretted that no topographic map of the area was available, for accurate geologic mapping can scarcely be accomplished without such aid. It is a source of satisfaction to know that a party of topographers were at work during the summer of 1924 in Bethel and Randolph. When the Randolph quadrangle is completed, it will be a pleasure to map in the areal distribution of the rocks in these townships. Bethel has always been mapped as purely sedimentary, save for a single granite area on Christian Hill; but other granite areas have been discovered, as well as gneisses, diorites, and diabases, which will be found located on the accompanying map, Plate II.

Forty-seven (47) new rock samples were collected in Bethel and the adjacent townships. These were placed in the museum at Montpelier. This brings the number of the State samples collected in the eastern half of the State up to 900.

DRAINAGE.

The largest river in Bethel is the White River, which rises in Granville, flows in a southerly direction through Rochester, in a southerly direction in Stockbridge to the center of the township, where it turns somewhat abruptly and flows in a northeasterly direction out of Stockbridge, through the southeastern corner of Bethel. At Bethel village it turns abruptly and flows in a southeasterly direction into the Connecticut River at White River Junction. The largest tributary to the White River rises in Roxbury and flows in a southerly direction through Bethel, and empties into the White River at Bethel village. This stream is often called the White River, and the broad valley through which it flows is known as the White River valley. The stream itself should be known as the Third Branch of the White River. Gillead Brook and Camp Brook rise in the extreme western part of Bethel, flow easterly, and empty into the Third Branch of the White River. Lillie Ville Brook rises on the north slopes of Mt. Lympus, flows in an easterly and then southerly direction, emptying into the White River in Stockbridge. Locust Creek, otherwise known as Gold Brook, rises in Barnard, flows in a northerly direction through the southeastern corner of Bethel, and empties into the White River about two miles southwest of Bethel village. Cleveland Brook rises in Royalton, flows in a northerly direction, and empties into the White River about one mile southwest of the village of Bethel. The Second Branch of the White River flows from Brookfield through the eastern part of Randolph, the northeastern part of Bethel, and empties into the White River at North Royalton. There are numerous small streams in Bethel, but so far as known they have received no definite names. Therefore, their description is omitted.

TOPOGRAPHY.

The main valley is the one traversed by the Central Vermont Railroad. This valley extends in a northerly direction across the township a little to the east of the geographic center. It is a broad, U-shaped, fertile valley. The valley of the White River in the southeastern part of the township and that of the Second Branch of the White River in the northeastern part of the township are also U-shaped. They are all definitely pre-glacial. The valleys of Gillead, Camp, Lillie Ville, and Locust Brooks are in part pre-glacial and in part post-glacial. There are numerous transverse valleys that are V-shaped and in part, at least, post-glacial. This will hold especially true of the northern section of the valley occupied by Cleveland Brook.

The altitude of the village of Bethel is 569 feet. Randolph to the north is 691 feet. Royalton, southeast of Bethel, is 510 feet, and South Royalton is 501 feet. White River Junction, the outlet of the White River Valley, is 361 feet. The highest altitude in the township of Bethel is located one mile west of Lympus Corners, five and one-half miles west of the village of Bethel and three miles south of Rochester Mountain triangulation station. This altitude is 2,480 feet. To the east and the west of the main valleys, the altitudes rise rapidly, and steep ridges that are now pasture lands are common. An excellent illustration of this fact can be seen directly east of the village of Bethel. The topography of the township as a unit is rugged, and may be regarded as in the stage of late maturity.

GLACIATION.

The township of Bethel is mantled with morainic material to such an extent that the geologist is seriously hampered in the study of the field relations of the different terranes. This holds especially true in the western part of the township where the area is densely wooded. Often the continuous outcrop of a diabase dike can be followed with certainty for only a short distance on account of the heavy overburden of glacial material. Presumably, the second exposure of diabase only a few rods distant from a given outcrop and with the same strike belongs to the same dike, but it is not proven. Even the strike changes frequently in short distances. It is a characteristic of Vermont that when one dike appears in a given area several others are very apt to be present.

Evidences of glaciation and the general direction of the ice movement can be found in the striations still remaining on the more resistant rocks. The well-exposed outcrop of nearly pure white, vein quartz and the broad dike-like quartz outcrops are particularly prone to furnish this evidence. The Cambrian quartzites occasionally afford good illustrations of glacial grooving. The best exhibition of striations found in Bethel is on the exposed surfaces of the resistant phyllites to the east and the southeast of the granite area on Christian Hill. It is doubtful if better evidence of glacial grooving can be found elsewhere in Vermont. The directions recorded for the ice movement were due south, south 20 degrees east, and south 30 degrees west. In the White River Valley in Randolph there is a strike of south 25 degrees west, but this specific direction was not observed in Bethel.

The terminal moraine of recession has left boulder trains in its course, and often by following in the direction of some boulder train the intrusive rock was discovered which gave rise to these erratics. Occasionally, a dike that appears only a few feet, or even less, in width has given rise to many erratics. This holds especially true of the diabase dike in the densely wooded area on Oak Hill.

There is no positive evidence that local glaciers moved down the Gillead, Camp, and Lillie Ville Brook valleys. These valleys are gorge-like and crooked, at least in their upper courses, and no cirques were found in the highest altitudes in the western part of Bethel. The numerous sand and gravel deposits in the valleys represent the outwash of the terminal moraine of recession that traverses the area to the northward.

GEOLOGY AND PETROGRAPHY.

The geology of Bethel, like the geology of other townships in eastern Vermont, is intricate and complex. In fact, greater difficulty has been experienced in the interpretation of the Terranes of Bethel than has been encountered in any other township in the eastern half of the State. The sedimentaries consist of a series of highly folded and faulted metamorphics that always dip at high angles and are often cut by intrusives. These intrusives range from the acidic to the basic. Some of them are so highly metamorphosed that in the field it is extremely difficult to say

with certainty whether they are of igneous or sedimentary origin. Both the sedimentaries and the intrusives differ widely in age and in mineral composition. Not only has a careful study of the field relations been made to avoid the introduction of errors in interpretation, but also approximately one hundred microscopic slides have been prepared for petrographic study from Bethel and its immediate environs. The detailed study of these slides has brought out several exceedingly interesting facts, as follows: (1) A large decrease in the percentage of magnetite in the pre-Ordovician terranes. However, magnetite is very abundant in these formations in Rochester. (2) A rapid increase in the feldspar content of the sericite schists and sericitic quartzites. In the more northern areas feldspars have been absent from the quartzites, and sparingly present, if present at all, in the sericites. (3) The abundance of biotite in the sericite schists, so that the rock frequently becomes a biotitic sericite schist, instead of a typical sericite schist.

In the western part of the township the stratigraphy has been largely determined by apparent field relations and the study of the microscopic slides. In the eastern part of the township the stratigraphy has been determined by the discovery of new beds of graptolites in the impure slates and shaly limestones, both in Bethel and in Barnard. These diagnostic features of age are less abundant in the more slaty members of the Ordovician series in Bethel than they are in Braintree, Northfield, and Montpelier to the northward. Also, they are less abundant in the shaly limestones on Christian Hill and the more massive limestone around East Bethel than they are in Berlin, Montpelier, Calais, etc., in the more northern portions of the State. It is interesting to note that graptolites have now been found in more than 25 townships in eastern Vermont, and that each township traversed by the erosional unconformity between the Ordovician and the pre-Ordovician from the international boundary on the north to Woodstock on the south, a distance of about 125 miles, has yielded these important diagnostic fossils. The width of this belt so frequently carrying crushed graptolites is sometimes 12 or 15 miles. It is not to be understood that they occur everywhere within this area, but by diligent search and the splitting open along planes of bedding of hundreds of samples of impure slates and limestones, graptolites can occasionally be found. It is regretted that thus far no fossils of any kind whatsoever have been found in the pre-Ordovician terranes in eastern Vermont.

ALGONKIAN.

It is not definitely proved that the Algonkian or pre-Cambrian terranes are represented in Bethel. Apparently, they appear in the extreme western part of Northfild, some 30 miles to the north of Bethel. This formation is either a highly feldspathic mica schist or an Algonkian gneiss. It requires field work in the township west of Northfield to prove definitely the age of this gneiss.

Contact between the Cambrian and the pre-Cambrian terranes has been followed as far north in Vermont as Stockbridge. The contact here is in the southwestern part of the township. The line of contact should, therefore, traverse Stockbridge to the southwest of Bethel and Rochester to the northwest of Bethel, and the line would fall a little to the west of the westernmost part of Bethel. However, there appears in Bethel a gneiss that extends southward into Barnard that may be Algonkian in age. The formation needs to be traced southward to ascertain its relation to the pre-Cambrian terranes to the southwest.

CAMBRIAN.

The term Cambrian as here used signifies a group of highly metamorphosed sedimentary rocks which lie between the eastern foothills of the Green Mountains and the erosional unconformity that separates the pre-Ordovician from the Ordovician. These formations consist of chlorite schists of sedimentary origin, hydromica schists, sericite schists, and quartzites. These formations cover nearly two-thirds of the area of the entire township. They are considered to have been derived from the erosion of the Algonkian terranes during Cambrian time.

The Cambrian terranes are divided into two groups, the Lower Cambrian and the Upper Cambrian. The Lower Cambrian consists of hydromica schists and chlorite schists of sedimentary origin. The Upper Cambrian consists of sericite schists and quartzites with some beds of chlorite schists and hornblende schists that may be of sedimentary origin. Certain chlorite schists are highly metamorphosed basic igneous rocks and, therefore, belong with the intrusives. The verd antique marbles and the talc deposits are all within the Cambrian terranes. These also represent metamorphosed basic igneous rocks.

The Cambrian terranes are regarded as sedimentaries added to the Algonkian land mass by the Green Mountain disturbance at the close of the Cambrian period. How much of the present schistosity of the rocks was introduced at that time is not known. It is, however, definitely proven that both acid and basic intrusives were introduced into the Cambrian terranes prior to the Ordovician time, for boulders of these intrusives appear in the Irasburg conglomerate which forms the base of the Ordovician series in eastern Vermont.

LOWER CAMBRIAN.

HYDROMICA SCHISTS.

The hydromica schists form so prominent a terrane in Bethel that it is now for the first time named the Bethel schist. It traverses the entire western part of the township, but beds of chlorite schist which sometimes appear to the west of the typical hydromica schist may also belong to the Bethel schists. In the typical development of the Bethel schists they are fine grained, greenish, schistose, highly metamorphosed sedimentary rocks which are more or less intimately associated with chlorite. These schists are, furthermore, characterized by numerous lenses, or eyes, and stringers of granular quartz. The quartz lenses, or eyes, vary in width from the small fraction of an inch up to five or six inches, and in length from an inch up to a foot. The smaller of these lenses sometimes suggest elongated quartz pebbles. Sometimes they cross the schistosity, but often they are elongated in the direction of the schistosity. The quartz in the stringers and the lenses, or eyes, is of the same granular type, and it is doubtful if the presence of pebbles can be proven. However, Professor C. H. Hitchcock at one time regarded this terrane as a basal conglomerate.

In the northwestern part of the township the strike of the Bethel schist varies from north and south to north 20 degrees east. The dip is at a high angle, often vertical, but with both easterly and westerly dips recorded. In the southwestern part of the township the strike varies from north 10 degrees east to north 20 degrees west, with high easterly dips prevailing. One of the best outcrops of the Bethel schist can be found on the southwestern slope of the high hill some two miles west of Stoddard Hill, and in the valley at the base of the hill and about one mile north of the old road on the north side of Mt. Lympus.

The Bethel schist is unquestionably older than the various members of the Missisquoi Group, for these latter terranes lie upon the eastern flank of the Bethel schist, apparently with a disconformity, for in the more northern sections of the State the Bethel schist is sometimes separated from the fine grained sericite schist of the Missisquoi Group by a basal conglomerate. If this conglomerate is not basal, then it must be regarded as interformational and the Missisquoi Group of terranes might then be regarded as Lower Cambrian.

CHLORITE SCHISTS.

If any of the chlorite schists of the western part of Bethel are of sedimentary origin, then these schists belong here. If they are of igneous origin, then their discussion belongs under the caption of intrusives. The chlorite schists occasionally conform in strike and dip with the hydromica schists already described. They occupy large areas, especially in the western part of the township. In the mapping no attempt is made to distinguish them from the hydromica schists with which they are associated. The area is largely wooded and drift covered, and accurate mapping would be extremely difficult.

The chlorite schists are fine grained, green, schistose, highly metamorphic rocks. They always dip at a high angle, and the vertical attitude is not uncommon. In composition the mineral chlorite, or some related mineral of the chlorite group, is their determinant constituent. They are characterized by a great abundance of epidote, and magnetite is invariably present. The epidote often intensifies the green color of these schists. Quartz and plagioclase feldspars are sparingly present. These schists are minus the granular quartz lenses, or eyes, that characterize the hydromica schists, but stringers of granular quartz are common.

In origin ferruginous clays by metamorphism could yield iron-aluminum silicates, which could subsequently alter to chlorite, but epidote is regarded as characteristic of igneous, rather than of sedimentary rocks. The presence often of much altered plagioclase feldspars introduces another phase to the problem, for these are wanting in the hydromica schist. While epidote is definitely known to result from the interaction of feldspars and ferromagnian minerals in igneous rocks, the great abundance of epidote in these chlorite schists demands further investigation along the lines of the origin of epidote.

MISSISQUOI GROUP.

UPPER CAMBRIAN.

The terranes regarded as Upper Cambrian are the sericite schists, sericitic quartzites, certain chlorite schists, and hornblende schists that may be of sedimentary origin. They occupy a larger area in Bethel than any other kindred group of rocks. The sericite schists are now characterized in part by the presence of biotite. Biotite began to appear in the sericite schists in the western part of Braintree, but only as a minor accessory mineral. The sericitic quartzite may be regarded as a highly quartzose phase of the sericite schist. Sericite is always present, but in certain localities the sericite content is very low. The chlorite schists often parallel the strike of the sericite schist, and occur sometimes in narrow bands folded in with the unquestioned sediments, and sometimes they occupy areas that may be considered highly metamorphosed igneous rocks. The hornblende schist, or the hornblendic sericite schist, is characterized by much hornblende, calcite, and magnetite. Some of them may be of igneous origin. Perhaps all of these formations should have been mapped in as sericite schists. They are, however, mapped as sericite schists and quartzites, for the mapping of the narrow chlorite beds would be extremely difficult, and the hornblendic phases are only local.

SERICITE SCHISTS.

The sericite schists of the Missisquoi Group have been continuous from the international boundary on the north southward for nearly 125 miles. Everywhere they flank the hydromica schist on the east and the Ordovician terranes on the west. The more quartzitic phase is normally near the center of this broad and thick belt of highly metamorphosed sediments. They are younger than the hydromica schist and older than the Ordovician terranes. Where the sericite predominates, the rock is classified as a sericite schist. Where well rounded quartz grains are in large excess over the mica, the rock is classified as a quartzite.

The sericite schists of Bethel are nearly all on the west side of the White River valley. A little north of the village of Bethel they appear on the east side of the valley for a distance of about one mile. The two belts are separated not only by the sericitic quartzite, but by a narrow belt of gneiss.

The general strike of the sericite schists is north and south, but a strike of north 10 degrees east is not uncommon, and near Lillie Ville in the southwestern part of the township the strike is north 25 degrees east. Toward the northwestern part of Bethel a strike of north 10 degrees west was recorded. The dips are always at a high angle with a westerly dip prevailing. The dips recorded are dips of the cleavage planes, and may or may not coincide with the bedding planes.

In structure the sericite schists are finely laminated schistose and granular. In some instances they will split readily into slabs three-sixteenth of an inch in thickness. In texture they are fine to medium grained. In color they are silvery white to a slightly greenish hue. The greenish color is due to a little chlorite derived from biotite. Possibly the green tinge in the sericite schists a little north of the village of Bethel is due to the chloritization of hornblende.

The essential minerals of the sericite schists are sericite and quartz. The normal accessories are biotite, magnetite, apatite, and pyrite. In some instances the biotite content in Bethel is so prominent a constituent that it becomes an essential mineral, and the rock should be classified as a biotitic sericite schist. This condition holds true also of hornblende, and the rock becomes a hornblendic sericite schist. Garnets appear also very abundantly on the east side of the White River valley, a little north of the village of Bethel, and on the west side of the river about two miles north of Bethel. These garnets are produced at times by contact metamorphism and often by regional metamorphism.

QUARTZITE.

The sericitic quartzites that have appeared in every township southward from the international boundary for a distance of nearly 125 miles are regarded as Upper Cambrian in age. These quartzites are always sericitic and graduate insensibly into the sericite schist which flanks the quartzites both on the east and on the west. This terrane is simply a very quartzose phase of the sericite schists. In some instances there is little else than quartz grains present and these are arranged in more or less parallel lines. sometimes separated by scaly or fibrous sericite.

In general this formation is fairly uniform in width. Sometimes it is lenticular. In Randolph it is narrow. In Braintree to the north of Randolph it is wide. In Bethel the belt is broken by gneisses, chlorite schists, and garnetiferous hornblende schists. Its general strike is north and south, and its dips are always at a high angle, sometimes to the east and sometimes to the west. On the west side of the river road to Randolph the strike was abnormal for the quartzite, north 30 degrees west, and the dip was to the northeast. In the southwestern part of the terrane the strike is north 10 degrees east and the dip is 75 to 80 degrees west. On the range of hills toward the northern part of Bethel there is a strike of north 5 degrees east, and a dip of 70 to 75 degrees east. On the same range of hills a little further to the west the strike recorded was north 85 degrees west and the dip was 35 degrees to the north.

Megascopically considered, the sericitic quartzites are schistose in structure, fine to medium grained in texture, silvery white to a slighly greenish-white in color and highly metamorphic. The only essential minerals are quartz and sericite. The accessory minerals usually present are biotite, oligoclase, corroded apatite, magnetite, and pyrite. A little epidote is sometimes present, and a part of the biotite may be altered to chlorite.

CHLORITE SCHISTS.

The chlorite schists occasionally conform in strike and dip to the enclosing sericite schists and sericitic quartzites. These beds are sometimes only a few inches in thickness, sometimes a few feet, and again they are hundreds of feet across the strike. The narrow bands of chlorite schist have been especially prominent in Bethel, both in the sericite schists and in the quartzites.

These chlorite schists are decidedly schistose in structure, fine to medium grained, and in color a dark green. The intensity of color depends largely upon the amount of chlorite present, but even this color is intensified by the presence of epidote. Chlorite, or some related mineral of the chlorite group, drawn out into more or less parallel layers is the essential constituent. More or less quartz is usually present. Magnetite is invariably present. In Bethel epidote is a common associate, apatite and crushed or granulated plagioclase feldspars have been observed in some slides.

A ferruginous clay by metamorphism could yield iron-alumina silicates which could be subsequently altered to chlorite. Secondary hornblende which is not uncommon in the Upper Cambrian terranes may have furnished a part, at least, of the chlorite. Biotite, in some instances, is known to be the source.

The narrowness of these beds, their conformity in dip and strike to beds of unquestioned sedimentary origin, frequently the presence of an appreciable amount of quartz, and the absence of any alteration by igneous intrusions in the walls of the enclosing sediments leads to the conclusion that these chlorites are highly metamorphosed sedimentary rocks. Their age would be the same as the enclosing sericites and quartzites, Upper Cambrian.

HORNBLENDE SCHISTS.

If any of the hornblende schists of Bethel are of sedimentary origin, then they belong here. If not of sedimentary origin, then the proper place for treatment would be under the caption of intrusives.

The area in question begins within the northern limits of the village of Bethel, and extends in a slightly northwesterly direction to the northern slopes of Blueberry Mountain, a distance of approximately three miles. The southern two-thirds of the area is on the east side of the White River valley, and the northern third is on the west side. The belt is nowhere known to be more than 15 to 20 rods in width. Its eastern and western boundaries are very irregular.

While normally a north and south strike might be expected, provided this terrane is of sedimentary origin, on the northwest slope of Blueberry Mountain the strike is north 75 degrees west and the dip is to the northeast 55 degrees. A little east of the north end of the village the strike of the hornblende schist is north 5 degrees east and the dip is at a high angle to the east.

The structure of the rock is schistose. Much of the hornblende is arranged in parallel lines, oftimes alternating with fine granular quartz. The texture is fine to medium and granular. The color is some shade of gray, but the sections richer in hornblende have the darker hues. The lighter gray shades are often spotted with long crystals of nearly black hornblende.

The essential minerals are hornblende and quartz. The accessory minerals are plagioclase, biotite, chlorite, calcite, magnetite, epidote, and often well crystallized garnets in rhombic dodecahedrons. This last phase is particularly well developed just north of the village of Bethel. It is again well represented on the east slope of Blueberry Mountain. In each of these localities the rock may well be classified as a garnetiferous hornblende schist.

The arguments that this terrane is of sedimentary origin are: (1) The gradation from outcrops particularly rich in hornblende to sericite schists and quartzites in which only a few hornblende crystals appear; (2) the occasional alternation of narrow bands particularly rich in hornblende with equally narrow bands extremely low in hornblende; (3) the bifurcation of long crystals of hornblende that appear fresh and of later generation than the main mass; (4) the presence of many well developed crystals of hornblende whose longer axis is across the schistosity of the rock; (5) the absence of any definite visible contact with rocks of unquestioned igneous origin.

The terrane, as a whole, is much folded and crumpled, and the different layers vary widely in composition and color. The terrane suggests one that has been highly metamorphosed by some deep-seated intrusive acting as one of the agents of metamorphism.

ORDOVICIAN.

The Ordovician terranes lie to the east of the Cambrian formations already described, and occupy less than one-third the area of the township. They are the widest in the northern part and pass out of Bethel into Royalton on the southeast.

The Cambrian and Ordovician groups are separated from each other by an erosional unconformity that has been traced in a northeasterly and southwesterly direction, now nearly north and south, for more than 150 miles. It extends into Canada for a considerable distance on the north and has been followed southward from Bethel through Barnard and Woodstock. Just where it crosses the Connecticut River to the southeast or where it enters Massachusetts on the south is only a matter of conjecture. The Ordovician terranes in Bethel consist of limestone, marbles, phyllites, and slates.

IRASBURG CONGLOMERATE.

The Irasburg conglomerate with its striking characteristics as seen in Coventry, Irasburg, Albany, Craftsbury, and Northfield does not appear in Bethel. Evidently erosion has not been carried as low on the Ordovician terranes in Bethel as it has in the more northern areas. However, the erosional unconformity extends southward from Bethel, through Barnard and Woodstock.

WAITS RIVER LIMESTONE.

The Waits River limestones traverse Bethel in two belts separated from each other by a rather broad belt of phyllite. In Randolph to the north of Bethel there were three belts of limestone separated from each other by belts of phyllite. The easternmost belt passed out of Randolph into Tunbridge and does not appear in Bethel. The easternmost of the two limestone beds in Bethel occupies a limited area in the northeast corner of the township. The village of East Bethel is situated upon this limestone. The terrane extends in a southerly direction into Royalton. It does not exceed one mile in width, even in the widest portion. This eastern belt belongs to the Waits River phase, which is lighter gray in color than the Washington phase, and often closely plicated. Some of the beds are sufficiently massive

PLATE III.

Sharp folds in garnetiferous slate showing variation in schistosity and bedding planes, Bethel.

and recrystallized to receive a handsome polish and are, therefore, a marble best suited for decorative interior work, for upon exposure to the corrosive agents of the atmosphere, the stone ultimately weathers to a rusty brown.

In structure some of the beds are massive, while others are shaly. In texture it is fine to medium grained. In color it is a medium gray, often banded with nearly white layers. Its essential mineral composition is calcite and quartz. In many instances the calcium carbonate has been completely recrystallized, and under the microscope shows perfect rhombohedral cleavages. The accessory minerals are a few scales of muscovite and occasionally biotite, best seen on the weathered surface of exposed outcrops, and either a few microlites of pyrite or a carbonate containing a little iron carbonate. Uncombined carbon provides the pigment.

The westernmost belt of the Waits River limestone in Bethel occupies the northern part of the White River valley. A little north of the village of Bethel this limestone is found only on the higher altitudes on the east side of the White River valley. It represents the Washington phase of this quartzose marble. The beds are often massive, but even thin shaly beds may appear in outcrops that are normally massive. In texture it is fine grained, and often compact. Its color is normally a dark gray without the lighter bands of the Waits River phase. The essential minerals are calcite and quartz. There is little or no evidence of the sorting of these essential minerals, thereby producing schistosity. The accessory minerals are muscovite, a few small grains of apatite, and carbonaceous matter. This carbonaceaus matter uniformly distributed throughout the rock is responsible, in part at least, for the uniform dark gray color. The terrane is thoroughly metamorphosed, susceptible of a high polish and, therefore, a quartzose marble.

A much smaller area of gray, shaly, graptolitic limestone is found just east of the high ridge to the east of Bethel village and west of the road leading to the granite quarries on Christian Hill. In the neighborhood of the granite quarries on Christian Hill in the area that essentially constitutes the eastern and broadest belt of phyllite, there are numerous beds of quartzose marble or calcitic quartzite which are interbedded with the phyllite and whose separate mapping as limestone would be extremely difficult. In the short railway cut at the Bethel-Royalton town lines on the road leading to the granite quarries on Christian Hill there are seven beds of limestone interstratified with the phyllite schist. These beds seldom exceed two feet in thickness. The strike is north 18 degrees east and the dip is 66 degrees east.

The Waits River limestones were traversed southward beyond the village of Barnard. They cross Locust Creek about one mile north of the village and appear upon both the east and west sides of Barnard village. As this section of Barnard is represented on the Woodstock quadrangle which has been published, it will be a pleasure to map in this geology with greater accuracy than is possible in the absence of topographic maps.

MEMPHREMAGOG GROUP.

The Memphremagog Group consists of slates and phyllites. The slates have furnished an unbroken terrane from Lake Memphremagog southward for more than 100 miles. The phyllites have been more or less broken in their continuity by limestones. In the northern part of the State the slates predominate, and in Bethel and doubtless to the southward the phyllites predominate. The slaty character was so pronounced in Newport and Coventry that the terranes were named the Memphremagog slates. In the more southerly extension of these terranes the two easternmost members soon lost their slaty characteristics and became phyllites. In Bethel the westernmost belt is nearly all phyllite.

It has been obvious for a long time that these phyllites should receive a more definite name and, therefore, the name Randolph phyllite has been selected for them. These phyllites should not be embraced in the Bradford schists, for these overlie the Waits River limestone. This is evident in the township of Bradford, which is nearly all schist, and in St. Johnsbury, where the Bradford schists are removed as waste on the top of a marble quarry. Neither can they be included in the Orleans phyllite of Professor E. C. Jacobs, for this underlies the Waits River limestone and is, therefore, older than the limestones. The phyllites that are here named Randolph phyllite are interbedded and interstratified with the Waits River limestones. The term Bethel phyllites would have been equally appropriate, but the term Bethel has been applied to the hydromica schists which in this township have so characteristic a development. In Randolph the phyllites extend across the entire township in a north-south direction.

SLATE.

The Memphremagog slates of Newport, Coventry, Montpelier, and Northfield have been reduced in Bethel to a very narrow belt that has largely lost its fissility so that it is no longer a commercial possibility. It flanks the easternmost belt of the sericite schist on the east and the Washington phase of the Waits River limestone on the west. Its general strike is north and south, and its cleavage dips are usually to the west.

On the east side of the road to Randolph, and near the schoolhouse at the Bethel-Gillead road, the western slate belt has become a highly garnetiferous phyllite schist. The schistosity and fracture cleavage are nearly at right angles to each other. The strike of the schistosity is east and west, with a dip of 25 degrees to the north. The fracturing and curving foliae strike north 10 degrees

PLATE IV.

Closely folded phyllite one mile west of Royalton Center, Royalton.

west with a dip of 75 degrees east. This condition is illustrated by Plate III.

PHYLLITE.

The township of Bethel is traversed by a broad belt of Randolph phyllite. It is flanked upon the east by the Waits River phase of the Waits River limestone and upon the west by the Washington phase of the same limestone. It is also more or less broken by small beds of limestone whose strikes and dips conform to those of the phyllite and, therefore, interstratified. Plate IV.

The strike of this terrane as a unit would be nearly north and south. In the southeastern part of Bethel a strike was recorded of north 15 degrees east with a dip of 63 degrees west. Near the village of Bethel the strike is north 5 degrees east and the dip, 90 degrees. On the west side of Christian Hill the strike is north 10 degrees west and the dip 60 degrees west. On the east side of the same hill the strike is north 5 degrees east and the dip, 90 degrees. On the top of the hill east of Bethel village the strike was north 10 degrees west, and the dip nearly vertical, but within 20 feet the strike changed to north 25 degrees east. The outcrop is intensely folded and filled with quartz stringers.

In color the phyllites are either a very dark gray or bluish-gray. In structure they are schistose. In texture they are fine grained. The essential minerals are quartz, muscovite and biotite, although it does not follow that both muscovite and biotite must be present in the same slide. The accessary minerals are pyrite, magnetite, apatite, and garnet. Carbonaceous matter is often present in large amounts and imparts the dark gray color to the rock. Often it is reduced to graphite. Garnets are very often so abundant that the rock should be classified as a garnetiferous phyllite. A limonite stain is a common decomposition product of the pyrite.

ACID INTRUSIVES.

GNEISS.

The rocks in Bethel classified as gneisses are foliated granitoid rocks that correspond in mineralogical composition to some of the plutonic rocks. In texture they are medium to coarse grained. The fine to medium grained feldspathic rocks that are more or less laminated and high in their granular quartz content have already been described as feldspathic quartzites. They might have been designated as arkoses.

Gneisses have been wanting in eastern Vermont southward from the international boundary to Bethel, save in the mountainous region in the western part of Northfield. Even here the gneiss does not entirely correspond to the gneisses of Barnard and Bethel. There has often been observed a gneissoid structure in the border of the granite masses in eastern Vermont and Canada, which structure has been attributed to flowage. But no gneisses have hitherto been observed that are the product of dynamic metamorphism. Plate V.

The gneiss in question was first observed in the railroad cut of the Central Vermont Railroad about two miles north of Bethel village. It is overlain by chlorite schists of igneous origin which send off apophyses into the gneiss. At the south end of the cut the gneiss attains an altitude of some 25 feet higher than the chlorite schists in the cut. Plate VI.

This gneiss appears again on the east slope of the hill directly west of the village of Bethel. The strike of the outcrop was north 10 degrees east, and the planes of foliation dipped at a high angle to the east. Outcrops of this gneiss were not exposed between the northern end of this outcrop and the gneiss in the railroad cut above cited. This does not prove that the two are not connected, for there is a heavy mantle of soil over the area.

Gneiss appears again in the southeastern corner of Bethel and south of White River. It also appears in both Royalton and Barnard. In Barnard it provides a continuous outcrop for several miles. It forms a prominent ridge on the west side of Locust Creek north of the village of Barnard, but before it enters Bethel on the north it appears on both sides of Locust Creek, where it forms a very prominent ridge on either side of the creek. It is not definitely known that this gneiss is connected with the gneiss in the central outcrop in Bethel, but such a connection may be assumed.

In color the rock is light gray tinged with green from the presence of a little chlorite and epidote. In structure it is gneissoid. In texture it is medium to coarse grained. In mineral composition quartz and albite to albite-oligoclase are the most abunbant constituents. Biotite exceeds the muscovite or sericite. Orthoclase, chlorite, epidote, magnetite, and a few small grains of apatite are accessaries. The chlorite and epidote are secondary. Secondary sericite is derived from the feldspars.

Since this gneiss forms so prominent a terrane in Barnard, and since the term Bethel has been selected for the hydromica schist which traverses the entire western part of Bethel, the term Barnard gneiss has been chosen for this formation. Its exact age is unknown. That it is pre-Ordovician seems certain, and it may be pre-Cambrian.

The gneiss in the railroad cut above mentioned is traversed by an aplite dike some two feet in width, and the gneiss directly west of the village of Bethel is either flanked or cut near its western border by an aplite mass some thirty feet in width and 1,000 feet or more in length. Whether or not this aplite belongs to the dike cutting the gneiss in the railroad cut is not definitely known.

GRANITE.

The largest and best known granite outcrop in Bethel is situated on Christian Hill about three miles northeast of the

PLATE V.

Chlorite schist overlying Barnard gneiss. R. R. cut two miles north of village, Bethel. Head of hammer at line of contact.

PLATE VI.

Sharp folded Barnard gneiss and chlorite schist, Bethel.

village of Bethel. It is somewhat eliptical in shape. It is more than one-half mile in length and some 700 feet in breadth. It cuts the Ordovician phyllites. About 1,000 feet to the east of the main mass of granite there is a shorter and narrower outcrop of a granite cutting the phyllites, but with some narrow beds of limestone between the two granite masses.

The main granite mass on Christian Hill appears to be a truncated arch or dome with a sheet structure dipping toward the east. On the east side of the outcrop the dip of the granite sheets varies from 15 to 45 degrees, and on the west side the dip is 30 to 35 degrees east. See Plate VII.

The white granite of Bethel is surrounded by a finer grained, light gray granite some 40 feet in width. Its fineness of texture is due to the more rapid cooling of the walls of the enclosing schist. The contact between the fine and medium to coarse grained granite is north 15 degrees west, and the dip is 60 degrees east.

On the eastern border of the Ellis Brothers quarry, which is separated by only a few feet from the quarry of the Woodbury Granite Company, there is a narrow belt of Orbicular granite. The orbules lie in sheets parallel to the flow structure, and the major axes of the orbules are parallel to the micaceous flowage bands. The orbules themselves are much smaller than the orbules in Northfield and Craftsbury, and far less abundant. They consist essentially of discoid masses of biotite encasing some small grains of quartz and feldspathic particles. They suggest a basic segregation of the most basic material in a magma more basic than that which represents the main white granite.

The granite contains some inclusions of a very dark colored, almost black mica schist some two feet in length and about one foot in thickness. This schist consists of biotite, quartz, orthoclase, and oligoclase. It is decidedly schistose, and does not appear in any way as Ordovician. It was probably brought up from pre-Ordovician rocks upon which the Ordovician sediments were deposited.

There are also inclusions of a syenite gneiss consisting of orthoclase, oligoclase, biotite, epidote, titanite, and leucoxene. It is obvious that this syenite gneiss is also pre-Ordovician.

The phases of the granite mass on Christian Hill are: (1) Glassy border from one to two millimeters in thickness; (2) fine, slightly parphyritic granite 20 feet in thickness; (3) fine grained, light gray granite richer in biotite than the main mass, 20 feet in thickness; (4) medium to coarse grained white granite of the main mass; (5) orbicular granite in narrow zone on the eastern border.

T. N. Dale in Bulletin 404 of the U. S. Geological Survey, page 111, characterizes the Bethel granite as a quartz monzonite of bluish milk-white color, of medium to coarse texture, and gives its constituents in descending order of abundance as "clear, colorless, rarely bluish quartz, with hair-like crystals of rutile and with fluidal and other cavities in sheets, with rift cracks parallel thereto; bluish milk-white soda-lime feldspar (oligoclase) slightly kaolinized and micacised; clear potash feldspar (orthoclase) slightly kaolinized, with very little microcline; muscovite (white mica), and very little biotite (black mica). The accessary minerals are apatite, titanite, zircon and rutile. No magnetite or pyrite was detected. The secondary minerals are kaolinite, a white mica, epidote, zoisite in some abundance, and very little calcite."

The term quartz monzonite as applied by Dale to the Bethel granite and many other granite outcrops in Vermont is misleading. It is not in keeping with the idea that Brögger had in mind when he applied the term monzonite to a transitional and intermediate group of rocks between the syenites (potash feldspar series) and the diorites (lime-soda feldspar series). The true monzonites contain the potash feldspars and the lime-soda feldspars in approximately equal amounts, and only when a little, but not much, quartz is present do these rocks become quartz monzonites. In the granites of Vermont, hitherto listed by all writers as quartz monzonites, quartz is an essential and very abundant constituent. It would seem better, therefore, to draw a distinction between the granites in which the potash feldspars are in excess over the lime-soda feldspars and those in which the lime-soda feldspars are in excess of the potash feldspars, and to call the former potash granites and the latter soda granites. In the list of the potash granites would fall the well-known biotite granites of Barre, Calais, Newark, and Woodbury. In the list of the soda granites would fall Bethel, Cabot, Chelsea, Derby, Dummerston, Groton, Hardwick, Irasburg, Kirby, Orange, Randolph, Rochester, Ryegate, Strafford, Topsham, Tunbridge, Vershire, Westmore. From the above tabulation it will be obvious that the ratio of the soda granites to the potash granites is more than 4 to 1 in favor of the soda.

The Bethel granite is widely used in structural work, monumental work, and statutary. It lends itself readily to most delicate carving as seen on the capitols of many columns. Perhaps two of the best known structures erected with Bethel granite are the Union Station in Washington, D. C., and the new Capitol of Madison, Wisconsin.

About 1,000 feet to the east of the main mass of granite on Christian Hill there is a smaller outcrop of similar granite with its longer axis roughly parallel with that of the main granite outcrop.

On the farm of Herbert Fifield, near the cemetery just outside the village limits on the south, there is a lenticular mass of granite 50 rods in length and 7 rods in width. It is different in

PLATE VII.

Granite quarry, Christian Hill, Bethel. Showing sheet structure and easterly dip.

texture from the granite on Christian Hill, and much coarser than the Randolph granite. It has never been quarried. Its essential minerals are quartz, albite to albite-oligoclase, orthoclase, muscovite, and a few scales of biotite. Its accessary minerals are apatite, zoisite, and secondary epidote.

About one-half mile northeast of the Christian Hill granite there is a small outcrop of soda granite that is slightly coarser in texture than the Randolph granite and finer in texture than the Christian Hill white soda granite. Its mineral composition is essentially the same as the Christian Hill granite.

On the farm of A. C. Quimby on Stoddard Hill some three miles west of Bethel there is a small outcrop of an extremely fine grained and white granite that has been quarried and used in the construction of the National Bank in Bethel. This granite is whiter than Randolph granite, and of much finer texture than the Christian Hill granite. It is a beautiful sculptural soda granite. Its essential minerals are quartz, albite-oligoclase, orthoclase, and muscovite. The accessary minerals are biotite, a few scales, apatite, zoisite, magnetite a few small grains, and secondary epidote.

On the Davis farm on the northeast side of Quimby Pinnacle, there is another small outcrop of granite practically identical with that on the Quimby farm. This granite has never been worked.

The granites of Bethel are all regarded as of Devonian age or possibly later.

INTERMEDIATE INTRUSIVES.

SYENITE.

With the discovery of a nephelite syenite in Braintree and a pargasite syenite in Randolph in the earlier work in these townships, it might be reasonable to expect that syenites would appear also in Bethel. However, in the wooded area about one mile south of the upper bridge over Cleveland Brook either in the southeastern corner of Bethel or the southwestern corner of Royalton, there appears an ill-defined and somewhat uncertain small outcrop of a syenite. Detailed field work in the southwestern corner of Royalton is needed to establish the area and the true definition of the rock. Its mineral composition in descending order of abundance is hornblende, oligoclase, a second feldspar that appears to be andesine, epidote, and chlorite. Quartz and apatite are absent. The chlorite and epidote are secondary.

BASIC INTRUSIVES.

Basic intrusives are fairly abundant in the eastern half of Vermont. They have invaded both the Cambrian and the Ordovician terranes, but are more abundant in the former than in the latter formations. The converse is true of the acid intrusives. The basic intrusives consist of diorites, diabases, gabbros, camptonites, amphibolites, pyroxenites, and peridotites. They are not all present in any given township, but in Bethel at least five of them have been found.

DIORITE.

The diorites are granitoid igneous rocks whose chief feldspar is plagioclase, often andesine, and whose chief dark silicate is hornblende. In a mica diorite biotite replaces the hornblende. Angite may be present in an appreciable amount, and the rock then becomes an augite diorite. An appreciable amount of quartz gives rise to the term quartz diorites.

A quartz diorite outcrop occurs about one mile south of the village of Bethel and south of the road to Gaysville. It is, furthermore, in the Cleveland Brook area, for at the upper bridge over Cleveland Brook the diorite crosses the brook. The mass appears somewhat lenticular, for it is more than 1,000 feet in length and approximately 200 feet in width. Its dimensions may be much larger, for the area is heavily drift covered, and definite contacts could not be determined. It appears to cut a very white phase of the Barnard gneiss.

There are at least four different phases of this diorite mass: (1) The main body of the mass particularly rich in quartz; (2) a hornblende schist phase in which the schistosity is very marked and the hornblende fresh and acicular or in long slender fibers; (3) a narrow zone of highly garnetiferous rock unusually rich in its magnetite content; (4) an epidotic and chloritic phase. The general strike is north 10 to 15 degrees east, and where schistosity is introduced the dips are 70 to 75 degrees east. The essential minerals are hornblende, albite-oligoclase, and quartz. Magnetite is accessory, chlorite, and sometimes epidote and calcite are present as secondary minerals.

A porphyritic diorite occurs either in the northwestern corner of Bethel or the southwestern corner of Randolph. The area is apparently small. In structure the rock is massive. In texture it is porphyritic with some of the plagioclase crystals more than one-half inch in length embedded in a greenish ground mass.

In composition the rock consists of hornblende, plagioclase much altered, chlorite, epidote, magnetite or ilmenite, and leucoxene. A few sporadic grains of quartz are present.

EPIDOSITE.

The epidosites are rocks consisting largely of epidote formed by the interaction of the feldspars upon the ferromagnesian minerals in the original parent rock. They are often fine to medium grained rocks of pistachio green color. Epidosite occupies an appreciable area on McIntosh Hill in the extreme northwest

PLATE VIII.

Chlorite schist overlying Barnard gneiss, two miles north of Bethel village. Hammer at base of contact.

PLATE IX.

Chlorite and ankerite on fracture plane in chlorite schist and Barnard gneiss, Bethel.

corner of Bethel. Epidote is the chief constituent present. There is also present a soda-lime feldspar, chlorite, magnetite, and a little quartz.

This epidosite is traversed by a small but exceedingly interesting epidotic quartz vein. In width the vein is from one to four inches. Its mineral composition is essentially quartz and epidote. In some sections the quartz appears in excess of the epidote, in others the epidote is in excess. A very little chlorite may be present. The vein appears to be of hydrothermal origin and the epidote to have been contemporaneous with the quartz rather than of subsequent development.

A slide was made of one of the well epidotized walls of this vein. The mineral composition of this rock was epidote, chlorite, soda-lime feldspar, a little quartz, and magnetite.

What the original rock that under shearing stresses in metamorphism gave rise to the epidosites and the epidotic chlorite schists is not known, but presumably it was a diorite. How such an abundance of epidote was introduced, whether by the interaction of the plagioclase feldspars upon the ferromagnian minerals, or by hydrothermal solutions, is a research problem still being continued.

CHLORITE SCHIST.

Chlorite schists are very prominent in Bethel. Many of them might be catalogued as epidote schists, especially where the ferromagnesian silicates and the plagioclases have established mutual relations. This condition holds true of the extreme western part of the township, and also of some of the outcrops on Paul's Peak. They appear to have arisen as phases of the metamorphism of rocks rich in augite or hornblende, such as the diorites, diabases, and amphibolites. Plate VIII.

These schists normally contain chlorite and epidote in great abundance and plagioclase crushed and granulated. Some quartz is usually present, and magnetite is invariably present. They are of greenish color, usually schistose, but planes of schistosity may be wanting. This latter condition holds true in an outcrop about one-half mile north of the village of Bethel and east of the east road leading from Bethel to Randolph.

A little east of the northern limits of the village of Bethel the schistosity is very marked. The chlorite schists appear in certain outcrops as if interbedded with a feldspathic quartzite and, therefore, of sedimentary origin. In other outcrops in the same general locality they appear in a manner extremely difficult to explain by any other interpretation than that of igneous origin, for they encircle the exposed edges of schistose or gneissoid rocks and send branches of chlorite schist downward across the schistosity of the enclosing rock at an angle of approximately 45 degrees. This condition suggests a fault and a complete overturn. Plate IX.

In the railway cut some two miles north of the village of Bethel chlorite schists overlie the Barnard gneiss. These schists send off apophyses into the gneiss in such a manner as to strongly suggest an igneous origin. Furthermore, at the southern end of the cut the Barnard gneiss rises some 30 feet above the chlorite, a condition that cannot be explained by sedimentation. Perfect rhombohedral crystals of ankerite, associated with practically pure chlorite, are abundant in the fracture planes in the face of the railroad cut. Plate X.

AMPHIBOLITE.

In the wooded area northwest of the Dunham farm on Oak Hill there is an outcrop of what appears to be either an amphibolite, or some other basic igneous rock, now altering to a chlorite schist.

It appears to cut the rocks now chlorite schists at an angle of 15 to 20 degrees. Its color is a dark green. Its structure is massive, but sometimes slightly schistose. Its texture is medium to coarse grained. Its mineral composition is hornblende, chlorite derived from the hornblende, plagioclase more or less granulated, epidote, magnetite or ilmenite quite abundant, a few sporadic grains of quartz, and apparently a little leucoxene.

CAMPTONITE.

About one mile south of the village of East Bethel there is a camptonite dike extending in an easterly direction into Royalton. The color of the rock is a dark gray speckled with phenocrysts of basaltic hornblende and nearly white plagioclase. The plagioclase crystals sometimes exceed one inch in length, and the hornblende one-half inch in length. The structure of the rock is massive and the texture medium to coarse and porphyritic. Its mineral composition is hornblende, augite, plagioclase, both andesine and labradorite. Quartz is absent and magnetite is present.

DIABASE.

Dikes of diabase occur in Bethel in both the Cambrian and the Ordovician terranes. That they are post-Devonian in age is proven by the fact that one of them cuts the granite mass on Christian Hill nearly in the center, thereby separating the granite quarries of the Woodbury Granite Company from those of the Ellis Brothers. The dikes may be as late as the Triassic.

The dike separating the two large granite quarries is from 10 to 12 feet in width and its strike is north 80 degrees east. It is a dark colored, massive, fine grained, ophitic rock whose essential mineral constituents are augite and labradorite. Apatite and magnetite are rare. Quartz is absent.

A second dike was found on the western slope of the steep

PLATE X.

Contact of chlorite schist with Barnard gneiss, northeast of Bethel village.

hill some two miles west of Stoddard Hill and near the southwest corner of the township. It varies from one to two feet in width, and its strike is approximately east and west. In color this diabase is dark gray. In structure it is massive. In texture it is fine grained and microscopically ophitic. Augite and labradorite are the essential minerals. It differs from the preceding dike in that it carries a little hornblende; magnetite is exceedingly rare.

A third dike occurs in the wooded area on Oak Hill between Pauls Peak and Blueberry Mountain. This dike varies also from one to two feet in width, and its strike is approximately east and west. The rock is dark gray in color, massive, fine grained, and ophitic. Augite and labradorite are the essential minerals. A little chlorite is present, probably derived from hornblende; calcite is rare, and magnetite is very abundant.

A fourth dike occurs in the wooded area in the northwest corner of Bethel and about one-half mile from the talc outcrop. This rock is grayish-green in color, spangled with scales of biotite. In structure it is massive and in texture fine grained. It is classified as a mica diabase. Its mineral composition is augite, hornblende, chlorite, plagioclase, epidote, and magnetite. Quartz is very rare.

On the Bascom farm about one mile west of Royalton Center and in Royalton there is a diabase that cuts the Randolph phyllite and is flanked on either side by quartz lenses or quartz veins from two to four feet in width. The dike itself varies in width from 18 to 24 inches. Its strike is north 45 degrees east and its dip is 35 degrees to the northwest. This dike can be traced in the open pasture for about 30 rods. Its color is a dark gray. Its structure is massive. Its texture is fine grained and ophitic. Its mineral composition is augite, labradorite, a very basic variety, and some magnetite. No olivine was found in any of the diabase dikes in Bethel.

PYROXENITES AND PERIDOTITES.

The peridotite belt that is so conspicuous in northern Vermont has been followed southward into Bethel. It has already been traversed for a distance of approximately 200 miles. In Bethel there is one distinct outcrop of the peridotite mass, now verd antique marble, and four distinct outcrops of the pyroxenite phase, now talc deposits.

The verd antique marble occurs in the extreme northwest corner of Bethel about one mile north of McIntosh Hill and on property owned by Herbert McIntosh of Burlington, Vt. The outcrop is lenticular. The longer axis strikes north and south. The actual length and breadth of the deposit is unknown, but the supply is ample for commercial purposes. The marble has been quarried on a small scale. It is susceptible of a high polish as proven by polished samples. A polished slab of this marble is used as the top of the communion table in the Congregational Church in Randolph, Vermont.

The color of the unpolished stone is greenish-gray. The polished sample is green. The structure is massive and the texture fine grained.

The verd antique marble consists essentially of serpentine, variety antigorite, olivine, magnetite, and a carbonate are present. The carbonate is secondary.

Two of the four outcrops of talc in the pyroxenite phase of the peridotite belt in Bethel are also found on McIntosh Hill in the northwest corner of Bethel. Two openings have been made. One on the farm of Albert Bowen and the other on the farm of Bert Woods. Both openings are only a few rods from the road extending from the Beanville road in Randolph over the hill to the Bethel-Gillead road in Bethel. Both of the pits are south of the crest of the hill some ten rods. The Bowen property is on the west side of the road, and the Woods property on the east side. The opening on the Bowen property shows the talc to be in part massive and in part fine, fibrous talc. The massive talc bears some carbonate either ankerite or breunnerite. Where the carbonate content is low the talc reduces readily to a white gritless powder. The talc on the Woods property is more greenish in color and carries crystals of carbonate ranging from one to two inches in length. The entire outcrop is apparently more than 100 rods in length and lenticular in shape. It cuts the chlorite schists at an angle varying from 10 to 20 degrees, and again the strike of a small outcrop may be approximately parallel with the strike of the enclosing terrane.

A third outcrop of talc that has been worked somewhat is on the farm of G. J. Fish on the higher altitudes north of the Bethel-Gillead road; the altitude is 950 feet. This talc deposit is now leased by the Eastern Talc Company of East Granville, Vermont.

The average strike of the workings is north 30 degrees east. The width of the opening is about 20 feet. The lowest depth found was 15 feet, and the greatest length worked, 75 feet, although some trenching was done beyond the 75 foot limit of actual removal of the talc. The walls of the talc on either side are chlorite schist only a few feet in thickness, and these are flanked on either side by a sericitic quartzite. The strike of the quartzite is north 10 degrees east and the dip is nearly vertical.

The fourth outcrop of talc in Bethel is on the land owned by Fred A. Marsh in the northern end of the village of Bethel. The length and breadth of the massive talc, mineralogically known as steatite, is unknown because of the street that passes over it and the houses constructed upon it. This steatite has been quarried, sawed into slabs, and sold under the name of freestone. The product is sufficiently massive and pure for a much wider application.

PLATE XI.

Quartz vein in phyllite near southwest corner of Royalton.

QUARTZ VEINS.

The introduction of quartz veins into the Ordovician terranes in Bethel and its environs normally would call forth no comment. Large veins are particularly prominent in the crumpled phyllite about one-half mile east of the village of Bethel. A large vein traverses the phyllite in the western edge of Royalton. A photograph of this quartz vein appears as Plate XI, but the veins to which particular attention is called are found on the western slope of the steep hill north of Mt. Lympus near the southwestern corner of the township of Bethel. The larger of the two quartz veins on this slope is 30 feet in width and shows good rhombohedral cleavages or partings which may result either from a sudden chill by the enclosing walls or by stresses induced in the intense folding of the area.

The larger of the two quartz veins contains three lenses or zenoliths of either an highly epidotic chlorite schist or an epidosite that appear to have been rendered schistose before the introduction of the quartz. The evidence is that these quartz veins represent the solidification of an acid magma rather than being deposited from hydrothermal solution, because one of the zenoliths of the epidotic chlorite schist is oriented from the others by an angle of 20 degrees.

The zenoliths of phyllites and limestones found in the Vermont granites are often orientated through wide angles from the original position. A second argument in favor of the magma theory is that some of the narrow quartz veins in Bethel and its immediate environs carry an appreciable percentage of small feldspar crystals. If the magma theory holds true, then these quartz veins should be known as quartz dikes.

PALEONTOLOGY.

As yet no fossils have been found in the pre-Ordovician terranes on the eastern side of the Green Mountains. The relative age of these formations has been determined by their stratigraphic position, continuity, and lithological characteristics. They are unquestionably pre-Ordovician, for they furnish the pebbles for the Irasburg conglomerate which lies at the base of the Ordovician series in eastern Vermont.

The discovery of new beds of graptolites in Bethel and Barnard is significant. They are not as numerous nor as well preserved in Bethel and Barnard as in many of the more northern townships. They are occasionally present in the Memphremagog slates, in the limestones to the west of East Bethel, and in the shaly limestone north of the granite outcrop on the Herbert Fifield farm on the road leading to the granite quarries on Christian Hill.

Graptolites were also found a little to the north of the village of Barnard and also in the limestones about one-fourth mile east of Barnard. These discoveries, meagre as indeed they are, prove that the Memphremagog slates, Randolph phyllites, and the Waits River limestones in Bethel and Barnard are Ordovician in age. The southward extension of the limestone at East Bethel into Royalton will doubtless furnish graptolites when the geology of that township is worked in detail.

METALLICS.

About one-half mile east of the village of Bethel there is an abandoned opening or shaft in a chalcopyrite-pyrrhotite vein. The opening is some 25 feet in length, 15 feet in breadth, and 10 in depth. Good samples of pyrrhotite, chalcopyrite, and of the two minerals admixed were found in the partially filled shaft and on the dump. The ore closely resembles the lower grade copper ores in Corinth and Vershire in Orange County, Vermont.

CONCLUSIONS.

1. The faulted and overturned area just east and northeast of the village of Bethel demands additional field and laboratory work when the topographic map covering Bethel is released. The area involved contains both acid and basic intrusives now metamorphosed into schists and gneisses. Garnetiferous, hornblendic, chloritic, and calcitic schists that may be of sedimentary origin are intimately associated with either the Barnard gneiss or feldspathic quartzites.

2. Some of the chlorite schists that are intimately associated with the hydromica schists and sericite schists are highly metamorphosed sedimentary rocks. Where the bands of the chlorite schists are comparatively narrow they are regarded as of sedimentary origin. Other beds of chlorite schist that send off apophyses into rocks of igneous origin, stringers branching into numerous narrower lines crossing the schistosity of possible sediments at angles ranging from 5 to 45 degrees, and massive beds that reveal no apparent schistosity are regarded as of igneous origin.

3. The source of such an abundance of epidote in the epidotic chlorite schists and epidosites demands additional research to settle the questions: (1) Was the epidote all formed by the interactions of the plagioclase feldspars and ferromagnesian minerals assuming mutual relations? (2) Was the epidote introduced by hydrothermal solutions that played an important rôle in the intense metamorphism of the area? (3) Is a part of the epidote of primary origin introduced by an epidote bearing magma as is suggested by the quartz epidote vein or dike traversing the epidosites?

4. The large quartz veins like the one in the southwestern part of Bethel that contains three zenoliths of an epidotic chlorite schist or epidosite have solidified from the most acid phase possible in an acid magma rather than from a high temperature igneous solution. Crystals of feldspars with perfect cleavage in some of the narrower veins show the possible transition from what has long been known as quartz veins to pegmatite dikes.

5. The discovery in the Cambrian series or at least pre-Ordovician terranes in Troy and Westfield of sheared diorites, now diorite gneisses, and in Roxbury of metadiorites largely metamorphosed to chlorite schists, lends to the conclusion that the chlorite schists and epidotic chlorite schists of igneous origin in Bethel may have been derived from diorites. Yet, there occurs one outcrop of amphibolite on Oak Hill that shows the transition of this basic rock to a chlorite schist. These basic intrusions that have furnished the chlorite schists are regarded as of pre-Ordovician age, for they nowhere appear in the Ordovician terranes in eastern Vermont. The peridotites and pyroxenites may represent differentiation phases of the same basic magma, and they also are regarded as of pre-Ordovician age.

6. The freshness of the hornblendic and feldspathic rock in the Cleveland Brook area, listed in this report as a diorite, suggests a later age, and it may have had a different mode of origin. Sufficient arguments have not yet been deduced to prove that this outcrop represents a highly metamorphosed sediment folded into the Barnard gneiss.

GEOLOGY OF NORTHWESTERN VERMONT.

For a number of seasons Mr. Arthur Keith of the United States Geological Survey has studied the rocks of the northwestern part of Vermont, but has not published his conclusions until recently.

In the number of the *American Journal of Science* for February, 1923, Mr. Keith has an article on the Cambrian Succession in Northwestern Vermont in which he states some of the results of his work. This article is here reprinted as an important contribution to Vermont geology.

By reason of his extensive studies in the Appalachians, south of New England, Mr. Keith is perhaps better qualified to decipher the exceedingly intricate and, therefore, difficult problems which the rocks of the Green Mountain region present than any other geologist and while by no means all of the problems which our rocks offer have been solved, yet the following study of these rock masses may be regarded as a very distinct addition to our former knowledge.

It is also very fortunate that, following Mr. Keith's paper, it is possible to reprint a study of the trilobites found in course of Mr. Keith's explorations by so competent an authority as Professor Percy E. Raymond who has for years made a special study of these fossils. Professor Raymond's article was first published in the *Proceedings of the Boston Society of Natural History,* Vol. 37, pp. 389-466, Plates 12, 13, 14.

These articles are published in this Vermont Report with the full consent of their authors and of the editors of the periodicals in which they first appeared.

I am very glad to be able to add these papers to this Report because they are thereby made easily accessible to all who are interested in Vermont geology and, especially, because they are of so much importance in themselves.

Mr. Keith's paper for the first time gives geologists an orderly and definite arrangement of the complicated formations of the region taken up and no geologist after this can intelligently study this area without taking into consideration the results which are presented in this paper.

A sketch map of the region studied is given in the original paper but this is not reproduced here because anyone wishing to identify particular localities may readily find them by examining the more elaborate map given with the last article on Mineral Resources.

CAMBRIAN SUCCESSION IN NORTHWESTERN VERMONT

Arthur Keith,
United States Geological Survey.

INTRODUCTION.

Along the western border of Vermont the closely folded portion of the Appalachians runs in a general north-south direction from southern New England and New York into Canada. This belt of rocks has been the subject of diverse opinions among geologists for about three generations. Some geologists placed the rocks of this belt at the base of the Paleozoic section, while others assigned them to the middle of that section. For instance, a single formation known as the "Red Sandrock" has been assigned to various positions from basal Lower Cambrian to the Silurian (Oneida). The Taconic system of Emmons is founded upon these rocks, and the controversies as to facts and as to taxonomy which raged about that system are not even yet settled. In this paper, which is a preliminary statement of new results in stratigraphy and structure, no attempt will be made to enter into details as to these controversies. A few of the salient advances toward their settlement will be cited, however, so as to show the bearing of the present discoveries.

This belt of intensely deformed rocks runs the whole length of Vermont—160 miles. A preliminary analysis of the southern half of this belt including the northern half of the Taconic range has already been written by the author but is unpublished. The structure of this southern portion, as well as its stratigraphy, and the larger questions involved differ so radically from the northern portion that it seems best to describe the latter in a separate paper. The main facts and conclusions concerning this northern portion are accordingly presented herewith.

GEOGRAPHY.

The region under discussion is that part of the great Appalachian valley locally known as the Champlain valley. A considerable percentage of it is occupied by Lake Champlain, and it lies between the Adirondack Mountains of New York on the west and the Green Mountains of Vermont and their foothills. The eastern or Green Mountain side of the valley has a nearly north detailed stratigraphy and the fossils the characteristic and exceptional structure of the region was determined. The fossils are now (1922) classified by Walcott as of three ages—Lower Cambrian, Upper Cambrian, and "Saratogan." The Lower Cambrian and "Saratogan" fossils were given preliminary identifications by Schuchert, who had discovered the Lower Cambrian fossils jointly with the present author, and later were examined in detail by Walcott and referred to the horizons above mentioned. Lower and a few Upper Cambrian fossils had already been described by Walcott from Vermont, his Upper Cambrian then including Saratogan. As now understood by him and by Ulrich, Schuchert, and other paleontologists, the "Saratogan" fossils are younger than the true Upper Cambrian, or St. Croixan. The Saratogan fossils discovered in the bowlders of the Swanton conglomerate are thus the first of that age to have been obtained in Vermont. The position of each of the collections in the Cambrian sequence was determined by the work of the present author. Further discoveries by the author were made in July, 1922, in company with Dr. Schuchert; numerous cephalopods were found at the border of the village of Brandon in limestones (equivalent to the Williston limestone) and pronounced by Schuchert to be "Saratogan" and the same as those in the Swanton conglomerate bowlders. A new locality for Upper Cambrian fossils was found in 1922 by Messrs. Schuchert, Sayles, Swinnerton and the author, at the lower end of the gorge at Highgate Falls; Upper Cambrian fossils were very abundant and large collections were made.

In September, 1922, fossils of Black River (Mohawkian) age were found by Schuchert and the author in the Georgia slate in Highgate.

The term "Saratogan" is used here to denote the time of the Saratoga fauna of New York. This term was introduced by Dr. Walcott and used by the New York Survey as synonymous with Upper Cambrian. In 1910 it was used by Ulrich and Cushing as synonymous with "Ozarkian" in New York. In 1912 these beds were doubtfully retained in the Cambrian by Walcott, and the term was abandoned by him, in favor of St. Croixan, as a name for the upper series of the Cambrian. By other geologists these beds have been referred to the Cambrian and to various portions of the proposed "Ozarkian system." Thus there is an increasing tendency to exclude the "Saratogan" beds (Potsdam-Hoyt) from the Cambrian, on the ground stated by Walcott in 1912 that they "are not typically of Upper Cambrian age." Since the proper systemic position of these beds is in doubt, it seems preferable in this paper to quote the old term, without decision as to its inclusion in the Cambrian or a later system.

Stratigraphy.—The sedimentary rocks of this district fall into three groups or sequences, each prevailing in a distinct belt and each exhibiting important differences from the other belts.

These three sequences, originally far apart east and west, are now jammed together along great thrust faults. The western sequence is found almost wholly west of the Champlain fault, which lies along or near the eastern shore of Lake Champlain, and extends far southward through Vermont and New York. Most of the area east of that fault is underlain by rocks of the middle sequence. These rocks narrow southward and end west of Middlebury between the Champlain fault at Snake Mountain and another nearly parallel fault called the Weybridge fault. The latter fault gradually traverses the valley with a trend north and northeast until it joins the main fault at the border of the valley and the Green Mountains, about ten miles southeast of Burlington. Between the Weybridge fault and the Green Mountain border fault lies the eastern sequence of formations, from Middlebury northward to Essex, on Winooski River. Thence northward to Canada the eastern sequence forms a narrow belt along the mountain border fault. The eastern sequence cuts across the central sequence for 30 miles and south of the latitude of Middlebury is in contact with the western sequence, the middle sequence having been entirely overridden.

The eastern sequence begins with a heavy quartzite and forms a cycle through dolomite, marble, and limestone into slate. Most of these formations, and perhaps all but the upper two, are of Lower Cambrian age. The western sequence likewise begins with a quartzite (Potsdam), which is, however, of "Saratogan" age, and passes upward through a lithologically similar cycle of Ordovician dolomite, marble, limestone, and slate. The mass similarity of these two sequences is very strong, although the eastern sequence is considerably thicker, and it has required the positive evidence of fossils to demonstrate their distinctness. The central sequence also begins with a quartzite, passes upward in a general cycle through dolomite, limestone, and marble into slate. The basal quartzite is of Lower Cambrian age, the same as the basal quartzite of the eastern sequence; four of the formations are Lower Cambrian and are overlain by the Upper Cambrian Milton dolomite and Highgate slate, followed by the Middle Ordovician Swanton conglomerate and Georgia slate. The two lower formations of the central sequence differ materially from those of the eastern sequence of the age, while most of the overlying dolomites in each sequence are similar or the same.

Structure.—Most of the Champlain valley occupies a synclinal basin between the Green Mountain anticline on the east and the great dome of the Adirondacks on the west. This synclinorium shows older and lower rocks on the east on account of the general westward overlap and nondeposition of the older beds. This general overlap relation accounts for the great differences between the eastern and western sequences. The orderly succession of beds in the syncline is further greatly disturbed by north and south thrust faults with great westward movement. The two principal faults are the Champlain fault, near the east shore of Lake Champlain, and the Green Mountain border fault, along the west foot or border of the Green Mountains. In the Champlain valley north of the Taconic range deformation and shortening have been accomplished on these thrust faults with almost no visible folding. The contrast in this particular between the sliced structure of the Champlain valley and the hundreds of doubled up and overturned folds of the Taconic range is one of the most abrupt in the Appalachians.

Including the Champlain fault and the Green Mountain border fault, there are from three to seven faults in any single cross section, and the width of the belt between the fault is only from three to ten miles. In the entire belt there are only half a dozen places where distinct anticlines or synclines are present. The reason for this is probably to be found in the fact that all of the sequences are composed of heavily bedded and competent rocks, especially in their lower two-thirds. In these the tendency under pressure is to shear instead of to fold or crumple, and they are further qualified by being directly upon the pre-Cambrian rocks to transmit thrusts derived from them. Thin limestones and shales which lend themselves readily to close folding and crumpling are found only in the upper parts of each sequence. Such beds simply rode along on top of the massive rocks below them which transmitted the thrust. The truncation of successive formations along the Champlain fault is impressively shown northeast of Highgate Springs.

All of the faults dip to the east, some at high angles, while others are nearly flat. The Champlain fault at several places is within a few degrees of horizontal, but most of the faults appear from the meager exposures of them to dip at angles of 40 degrees or more. As a result the valley is cut into series of long, narrow slices, each rising westward upon the next slice. The total amount of shortening has not yet been worked out, but it is undoubtedly much greater than one-half of the original width. This district lay between the upthrust, advancing arch of the Green Mountains and the passive buttress of the Adirondacks against which the different formations abutted, which position was a sufficient reason for the extreme faulting and narrowing of the deformed belt. The fact of the great narrowing is further evidenced by the great westward swerving of the Green Mountain anticline and of the various folds lying to the east of it. This swerving or protrusion diverts the folds more than 10 miles west of their normal trend and position in Vermont, so that the axes of the folds run well to the west of north instead of east of north as is customary. A direct result of this excess compression is seen in the exceptional uplift of the lowest Cambrian rocks between Middlebury and Burlington, and in the eastward projection and uplift of the Cambrian and pre-Cambrian of the Adirondacks immediately to the west. Put in other words, one of the principal cross-anticlines of the Appalachians is shown here in close association with its cause—an unusually great westward thrust of the eastern masses.

The faults of this district are of three different ages: First came the flat overthrust of the Champlain fault; later on, probably in the same general epoch of folding, this was compressed, folded up, and dissected by later faults. This process has left numerous rather flat-lying and disconnected scales of the old overthrust mass, with parts of the underlying mass exposed between them by erosion. These features are well shown near Mt. Philo in Ferrisburgh, 12 miles south of Burlington. At a still later date normal faults were produced. These appear principally to the west of the Champlain fault and are numerous along the Adirondack margin. They trend well to the east of north, a direction considerably in contrast with the nearby thrust faults. In a few cases the normal faults appear to dissect and offset the thrust faults, but conclusive evidence of it has not yet been found. The Weybridge fault, three miles west of Middlebury, may be of this origin. The formations east of that fault are younger than those west of it, so that it is either a normal fault with the downthrow on the east or it is a thrust fault dissecting the old Champlain fault and thrust up younger rocks which previously had been covered by the overthrust. There are no data at present at hand to determine the age of the normal faults. The various thrust faults, however, are of the regular Appalachian type and, therefore, were probably produced at the end of the Paleozoic era. The general position of the Mountain Border and the Champlain faults is shown on the map.

DETAILED STRATIGRAPHY.

This paper concerns itself mainly with the rocks of the central sequence, which extends from the Canada border 70 miles southward to Snake Mountain, five miles west of Middlebury. The detailed succession of these rocks has been unknown until unraveled by the author in 1921 by detailed mapping and discovery of fossils. The older method of correlation between widely separated cross-sections failed to solve the problems, because no two sections ten miles apart gave the same succession, on account of the complex fault systems and overlaps. The western and eastern sequences will only be briefly treated in this paper in order to show the larger stratigraphic variations. The rocks of the eastern sequence have already been divided into formations and mapped over large areas by the author, and they will be made the subject of a separate paper. The rocks of the western sequence have not been thoroughly examined as a whole, although close work has been done in limited areas by various geologists.

CENTRAL SEQUENCE.

Monkton quartzite.—This is the oldest formation of the central sequence. Its base is not known, because the lowest beds rest on the Ordovician rocks along a thrust-fault plane. The name is taken from the town of Monkton, 20 miles nearly south of Burlington, where the relations of the quartzite to the overlying beds are well and repeatedly shown. The quartzite was included in previous reports with the overlying Winooski marble and the Mallett and Milton dolomites and the whole termed the "Red Sandrock."

Except for a small mass east of Highgate Springs, the Monkton quartzite is not found north of Lamoille River, eight miles north of Burlington, being there cut out along several thrust faults. For the same reason it disappears at the south end of Snake Mountain. In Monkton it forms several anclines on the major cross anticline already described. The general uplift there is higher and broader than elsewhere and brings this quartzite into direct contact along a fault with the Cheshire quartzite of the eastern sequence, which is of the same age. Owing to the superior hardness of the Monkton quartzite it resists erosion, and nearly everywhere its outcrop is marked by hills or low mountains. The lines formed by these are interrupted because the quartzite is cut out for short distances by faults.

The Monkton quartzite has a decided reddish color varying from reddish-brown through brick-red and purple to light shades of red, pink, buff, and white. The white beds are more numerous at the top, especially north of Burlington, where they are as important as the vari-colored beds. Striking contrasts are formed by the white and vari-colored layers, particularly in the cliffs along Lake Champlain. The formation consists almost entirely of quartzite in layers from a few inches up to three feet in thickness. A few seams and beds of reddish or purplish shale are interbedded with the quartzite in the lower part of the formation, most of them being only a few inches thick. In the upper part of the formation a few thin layers of gray or pink dolomite form a transition into the overlying Winooski marble. Quartz conglomerate in thin layers has been reported from a few places by several geologists but has not been observed by the writer.

The formation outcrops freely and forms extensive cliffs and ledges. Where it borders Lake Champlain the cliffs are nearly continuous, being mainly in the lower part of the formation. The upper part of the quartzite also makes very extensive exposures and forms large dip slopes which may show the surface of a single bed for 50 or 60 feet down the dip. On these broad exposures which are strongly mottled buff and red or

purple in addition to the wavy bedding. For decorative purposes this stone is sawed parallel to the general bedding plane, thus intersecting the mottling and the wavy surfaces and producing extremely variegated patterns.

At the base of the formation the dolomite is interbedded with quartzite layers for a thickness as great as 50 feet, forming a transition into the underlying Monkton quartzite. Just below the top of the Winooski there is a marked horizon of red, buff, and purple quartzite layers interbedded with pink and buff, mottled, fine-grained dolomite for a thickness of nine feet. In the pink dolomite just above this quartzite there are a few inches of edgewise conglomerate containing thin, flat dolomite pebbles. The quartzite layers at this horizon form broad, flat surfaces like those of the Monkton quartzite which they strongly resemble, and also show ripple-marks, mud-cracks, and annelid trails. These beds and the underlying mottled pink or purple dolomites aggregating 85 feet are well exposed at Winooski Falls in Burlington.

At this same topmost horizon, 11 miles north of Burlington and also 3.5 miles N. 20° W. of Highgate Center, a coarse conglomerate or breccia is found in several layers aggregating from 5 to 30 feet. The pebbles in the conglomerate are of various kinds of dolomite, gray, mottled pink, buff, or gray calcareous sandstone and quartzite, while the matrix is a sandy buff dolomite with the purple, slaty streaks characteristic of the Winooski. Many of the pebbles are more than a foot (as long as two feet were seen) in diameter with an average of five or six inches, and the majority are rather angular. In this conglomerate are scattered knots of brilliant red jasper of vein origin.

There is an abrupt change above the topmost quartzite of the formation to the massive gray beds of the Mallett dolomite. The formation thins southward from its greatest thickness of 400 feet about 12 miles north of Burlington. Along the east side of Snake Mountain the Winooski is very poorly exposed and is probably less than 100 feet thick.

Fossils have been found in the Winooski marble by many geologists. As early as 1847 a few were found by G. M. Hall and Perry and were assigned to the Silurian by James Hall. In 1861 Billings correlated them with the Potsdam. Walcott in 1883 found fossils in the pink dolomite and referred them to the Lower Cambrian.

Mallett dolomite.—Massive light and dark gray dolomites make up practically all of this formation. There are fine exposures of them on the shores of Mallett Bay (a part of Lake Champlain) five miles north of Burlington, for which the formation is named. Beginning 100 feet from the base there are two or three beds of fine white quartzite, cross-bedded and ripple-marked, and sandy dolomites are numerous, in many places grading into dolomitic sandstone. The sand in these beds consists of glassy, rounded quartz grains which stand out in relief on weathered surfaces. Between St. Albans and the Canada border a few beds of shale make their appearance between the dolomites. The bedding is usually plain and even, and most of the layers are less than a foot thick. Secondary quartz in geodes is common in the dolomites. A few beds of pink dolomite are seen here and there, apparently in the lower part of the formation, but these may be repetitions of the Winooski by faulting.

The beds of this formation are very hard and tough and resist erosion so as to make ridges wherever the formation appears. Large ledges are numerous and are usually weathered to a dark gray, or even a black surface. A few fossils of Lower Cambrian age were found by Walcott in some thin layers in the upper part of the formation in the towns of Georgia and Highgate.

The contact of this dolomite with the overlying Colchester formation is usually sharp, but a few sandy beds in each formation seem to make a rather poor transition between the two. The Mallett dolomite is between 700 and 800 feet thick, where all is present, but it is reduced to a thickness of 50 feet in the eastern part of Swanton township, probably by Lower Cambrian erosion.

Colchester formation.—This formation differs from preceding ones in that it contains numerous shaly and slaty beds with which are interbedded sandstones and dolomites. The formation is named for its good exposures from one to two miles north of Colchester village in the town of Colchester, which borders Burlington on the north. This formation extends from Canada to Monkton, where it is cut off against a thrust fault. South of that point its position in the eastern sequence is taken by a formation of similar aspect but with less shale and more dolomite.

The greater part of the formation is made up of shale in the northern sections. The amount of this diminishes southward and beds of calcareous sandstone and sandy dolomite become more numerous. The shales are usually dark or black, distinctly banded, and much speckled with little scales of mica. Interbedded with these are thin layers of gray sandstone locally argillaceous and in other places calcareous. In Highgate and Swanton the formation contains many non-banded massive layers, which weather light gray or white, and many very strongly bedded layers which are used for flagstones. A few layers of sandy dolomites are also present here and there.

A notable feature of the formation is a peculiar tough, dark gray dolomite which weathers with a brick-red surface. This forms lenses as much as five feet thick and 50 feet long near the base of the formation. Several of these are present in the section at the Parker quarry (now the Howard quarry), two miles and a quarter north sixty degrees west of Georgia. In Swanton they are numerous and prominent and are closely associated with a peculiar conglomerate formed of irregular dolomite bowlders in a slate matrix. The dolomite bowlders consist for the most part of the reddish-brown dolomite, but there are also some gray or sandy dolomite fragments. The whole group of beds appear to be of intraformational character.

The Colchester also contains another set of lenses consisting of massive blue marbleized limestone, sharply separated from the slate. They are best shown two miles southeast of Swanton, where two of them are surrounded by gray slate. The lenses measure 100 by 60 feet and 105 by 75 feet, the longer axes lying northwest-southeast. No thickness and no original relations to the slate can be determined, owing to the cleavage. Peculiar patches of rusty dolomite grade into the limestone, and the whole resembles a reef deposit. This limestone very closely resembles some of the bowlders in the later conglomerates, and even a whole lense may have become a bowlder. The contact of the formation with the overlying Milton dolomite is sharp and represents a hiatus, since the Milton is of Upper Cambrian age. One mile northwest of Highgate Center the contact shows a visible unconformity. The formation usually occupies narrow valleys or hollows.

This formation has furnished a large part of the Lower Cambrian fossils from Vermont, and most of them have come from the Parker quarry. The presence and age of the fossils there has long been known, and many fine museum specimens have been obtained there. Much material was excavated by Walcott and a fine collection secured. Another locality which promises to yield many Lower Cambrian fossils was found by the author in September, 1922. This is at a small flagstone quarry nearly three miles southeast of Swanton.

Edson reported the discovery of *Paradoxides* in shales in the town of St. Albans, which indicates strongly that Middle Cambrian is there present. He also reported finding Agnostus in the same place, thus indicating Middle Cambrian or later beds. It is thus possible that some of the shale called Colchester is of Middle Cambrian age, but it has not yet been practicable to distinguish such beds as a formation. If Middle Cambrian shales are present, they can only extend a few miles to the north and south before being cut out by the Milton dolomite. This possibility is strengthened through the finding by B. F. Howell at the same locality in 1922 of apparent Middle Cambrian fossils.

The thickness of the formation varies from 200 to 250 feet at the south and from 20 to probably 500 feet at the north. This fact taken in connection wtih the great reduction of the underlying Mallett dolomite in the township of Swanton gives evidence of important erosion and overlap.

Milton dolomite.—The beds of this formation are practically continuous from Canada to Monkton. They are best exposed in a wide belt passing through the town of Milton about three miles west of Milton village. The formation consists almost entirely of massive dolomite, both fine and coarse-grained. Most of the beds are thick (from one to four feet), especially in the lower part of the formation and, as a rule, the bedding is difficult to determine. The dolomites vary in color from dark bluish-gray or steel-gray through light gray to buff, most of them weathering with a dark surface. Beds of sandy dolomite are fairly common in this formation, as in the other dolomites in this region, but there is only a little dolomitic sandstone, mainly in the upper third of the formation.

A peculiarity of the Milton is its considerable content of black chert. This forms small, irregular patches and pockets much broken during the rock movements, and is very seldom found in layers. This chert weathers out in black spots which readily catch the eye. Chert is of rare occurrence in the formation of Vermont and its abundance in this dolomite makes it a very distinctive formation. Numerous large, rough ledges are made by the formation, much spotted with black chert and white quartz knots, or geodes with quartz crystals. In a few places there are doubtful cryptozoa near the top of the formation.

Another peculiarity of this dolomite is its large content of dolomitic conglomerate. This is present at many horizons throughout the formation and almost invariably appears at the top. The conglomerate is formed mainly of pebbles of dolomite and dolomitic sandstone, of which the source is probably the beds of the same character in lower parts of the formation. The dolomite pebbles are dark gray or bluish-gray to light gray and the sandstones are light or dark gray. A few pebbles of slate are also found. Most of the pebbles are decidedly angular, resembling a breccia, but some of them are rounded. The matrix of the conglomerate is dolomite and is like the bulk of the formation. The different colors of the pebbles and the matrix usually make plain the nature of the rock.

The beds resting upon the Lower Cambrian Colchester formation one mile northwest of Highgate Center are conglomerate and cut out six feet of the Colchester, bringing out the unconformity strongly. The upper 80 feet of the Milton at Highgate Falls consist of slabby dolomite and limestone interbedded with eight layers of conglomerate. All of the conglomerates resemble tillite in texture, but only one 15 feet from the top, contains bowlders of foreign origin. This bed is a giant conglomerate 26 feet thick, holding bowlders of many kinds of limestone up to eight feet in diameter. The enormous differences in size, kind, and angularity of the bowlders strongly suggest that this bed is a tillite. The evidence of glacial origin for the other conglomerates is weaker, and it is safer to call them intraformational.

The slabby limestone and dolomites near the top of the formation at Highgate Falls yielded in 1922 numerous fossils, mainly trilobites and brachiopods, which were determined by Schuchert to be Upper Cambrian. No fossils have been found in the middle and lower parts of the formation. Paradoxides heads have been found by Edson in the town of St. Albans and so identified by Walcott, therefore it is possible that the Middle Cambrian is represented either in the lower massive part of the Milton or in the higher part of the Colchester. The formation is about 800 feet thick where it is all present. The massive character of the beds makes precise measures of the dip and the thickness difficult. A few miles southwest and northwest of St. Albans the formation is entirely cut out by erosion preceding the deposition of the Swanton conglomerate.

Highgate slate.—This formation extends from Canada into the town of Milton, a distance of 25 miles. Its principal development is in the township of Highgate, where it forms a broad area. A fine section of the formation is shown at Highgate Falls, close to Highgate Center, and in adjoining areas. The formation consists mainly of dark slate, in places black, and usually banded. The banding is in most places regular, sharp, and clear, and strongly resembles the seasonal banding of glacial deposits. The dark and the light layers are evenly spaced and from one-eighth to one-fourth of an inch in thickness. In the lower part of the slate at Highgate Falls the light bands consist of fine sandy shale or sandstone seams. About 40 feet above the base at Highgate Falls there is a zone nearly 6 feet thick of a slate filled with small pebbles of limestone that range up to 4 inches across.

In the lower part of the slate at Highgate Falls are several beds of tough gray dolomite a foot or so thick and weathering to a rusty brown. These beds were folded and torn apart and their segments separated by many feet, and the banded slate flowed between and around them as if plastic. Thus is brought out an extreme deformation and shortening in a section that at first sight seems simple.

Interbedded with the slates are numerous thin seams of blue limestone an inch or two in thickness. These are very evenly spaced between layers of slate of about the same thickness and constitute a very marked horizon. One-third of a mile northwest of Highgate Center these layers thicken and outcrop in the railroad-cut as a strongly banded limestone mass 35 feet thick. These are probably the highest beds in the formation near Highgate. The thin limestone layers yielded fossil trilobites to the author in 1921 at numerous localities, the most important being in and near Highgate Center. A determination of these fossils by Walcott placed them in the Upper Cambrian. Locally these limestones thicken and form good-sized lenses. The most prominent instance is two miles N. 15° E. of Highgate Center, where a lense of blue limestone is 600 feet long and about 50 feet thick. Upper Cambrian trilobite fragments are common, along with some orthoid brachiopods and plates of cystids, but all are so poorly preserved as to be undeterminable. Brachiopods collected by Walcott near Highgate Falls and described by him in 1912 as of Upper Cambrian age turn out to be from the Highgate slate. Trilobites collected in 1922 by Schuchert and the author, two miles north of Highgate Center, are of Upper Cambrian age.

The formation is at least 300 feet thick at Highgate Falls. The amount of distortion and repetition as shown by the dolomite beds is enormous, and the top of the formation is cut off by a thrust fault in this section. No other reliable one was found, however, so that the original thickness of the formation is not known. Doubtless later formations of Upper Cambrian age were deposited on the Highgate, but nothing is known of them in this region. At several localities northwest and southwest of St. Albans the formation was removed together with the Milton dolomite by the pre-Swanton erosion.

Shelburne marble.—Outcrops of this formation are mainly in a wide band between the town of Colchester, three miles northeast of Burlington, and the town of Hinesburgh, 12 miles nearly south of Burlington. Two much smaller parallel strips of marble are found in the town of Shelburne in addition to the main belt. The name of the formation is taken from its many exposures in Shelburne. The marble there follows next above the Milton dolomite, a position which is occupied by the Highgate slate farther north.

The formation is composed almost entirely of marble, always light colored, and for the most part white. Other colors are light buff or cream, bluish-white, and various beds are mottled with cream and white or blue and white. A few thin beds of light gray dolomite are found in various parts of the formation. Ledges of the marble are fairly common on the hills and usually are conspicuous on account of their whiteness. As a rule the formation occupies low ground and is accordingly much covered with the sands and clays of the glacial epoch. For this reason there are no precise data as to the northern end and the upper and lower contacts of the formation. The marble shows a thickness of about 200 feet in the section along Winooski River, but no upper limit is there shown, and the whole thickness of the formation is doubtless twice as great.

Four and one-half miles north of St. Albans back of the estate known as Rockledge a mass of bluish or white marble was discovered which is possibly a part of the Shelburne or a marble lens out of the Colchester. This mass has the shape of a large lens about 170 feet long, 110 feet wide, and six or eight feet thick. Just south of this a similar marble mass measures 90 feet by 50 feet. The contacts with the underlying Highgate slate and the overlying Swanton conglomerate are sharp and distinct. The conglomerate passes north from the marble on to the

Highgate slate with a sharp and somewhat unconformable contact. No fossils are found in this marble, although extended search was made, but it is probably of Upper Cambrian age, since it overlies the Highgate and is beneath the unconformity at the base of the conglomerate. It is suggested, however, by Sayles that these marble masses are enormous bowlders in the base of the Swanton conglomerate. Their huge size is an obstacle to this conception and requires the additional concept of transport by ice as the most capable agent. Bowlders of eight and ten feet of the same kind of marble are common in the Swanton conglomerate, however, and one bowlder of 60 feet and a possible bowlder of 140 feet have been found, so that it is difficult to set a size which is too big for a bowlder. The existence of limestone lenses in the Colchester of comparable size and material ready to become bowlders lends support to this view.

No contacts are known between the Shelburne marble and the Milton dolomite, which is the next underlying formation. Where the formations cross Winooski River, nearly three miles east of Burlington, the Milton dolomite and Shelburne marble are conformable in dip, but their outcrops are separated by the width of the river. The same conformable relation holds elsewhere. Ten miles north of the end of the marble, however, in the town of Milton, a similar position above the Milton dolomite is occupied by the Highgate slate, which also appears to lie conformably on the Milton dolomite. Whether the Shelburne is older or younger than the Highgate is not yet proven, but probably the Highgate is older, as seemingly is indicated by the marble lenses above described. The disappearance of the Highgate southward may be due either to nondeposition or erosion. Upper Cambrian erosion is the more probable, in which case the Shelburne marble may have followed the Highgate in regular sequence.

Williston limestone.—The next succeeding formation is the Williston limestone. It outcrops in a single belt seven miles long beside the Shelburne marble in the towns of Williston, Burlington, and Shelburne. This formation consists of light or dark blue limestone and marbleized limestone. Interbedded with these are some layers of shaly blue limestone and a very little calcareous shale. There are also scattered beds of dolomitic limestone, usually dark blue or gray in color. The beds of this formation are fine-grained, even where the alteration into marble is extensive. Some of the blue limestones are moderately banded with light colored, argillaceous streaks and somewhat mottled with small nests of dolomite. The prevailing blue color and the notably thinner bedding of this formation distinguish it readily from the underlying Shelburne marble.

Fossils are very scarce in this limestone, owing to its greatly deformed condition. In July, 1922, a number of cephalopods and several Ophileta-like gastropods were found in the same formation in Brandon by Schuchert and the writer and were assigned by the latter to the "Saratogan." They are of the same species as those found in the fossiliferous bowlders in the Swanton conglomerates at Corliss Ledge. In September, 1922, Schuchert and Dunbar found trilobites and gastropods in the Williston limestone 4.2 miles southeast of Burlington and assigned them to the "Saratogan."

Owing to the thin bedding of the formation it is considerably crumpled, and there is no measure of the thickness, which is probably as much as 500 feet. There are no precise contacts between this limestone and the Shelburne, but the differences between the formations are marked, and the change from one to the other is probably abrupt. The Williston limestone is overlain in the towns of Williston and St. George by a fine black phyllite. This appears to lie conformably on the Williston, but its age relation to the latter is unknown.

Swanton conglomerate.—The bases of this formation begin about eight miles nearly south of St. Albans and appear at many localities northward to and across the Canada border. The conglomerate is well shown in the eastern part of the township of Swanton, for which it is named. The formation is not continuous but forms disconnected lenses at the base of the Georgia slate. These are common in the towns of St. Albans, Swanton, and Highgate, and unusually good exposures are seen about a mile nearly west of Georgia Center. Doubt would ordinarily arise to the desirablity of separating these beds as a distinct formation, or of including them in the Georgia, as has previously been done. Their taxonomic value, however, and the notable aspect of the conglomerate render it of much more than usual importance and justify it as a separate unit.

The formation consists largely of coarse limestone conglomerate, a highly specialized rock from which much is learned as to the history of the region. Associated with the conglomerate are many beds of calcareous gray sandstone, some calcareous quartzite, and subordinate layers of dark gray slate. The conglomerate forms lenses of all sizes up to 30 feet in thickness and three-fourths of a mile in length. The rock consists, as a rule, of a bluish-gray limestone matrix in which are embedded pebbles and great bowlders of blue limestone. In addition to the limestone pebbles, which make up most of the conglomerate, there are many pebbles and bowlders of fine white or bluish-white marble, gray calcareous sandstone, sandy limestone, and gray dolomite, and of a peculiar tough, dark-gray dolomite, weathering with a reddish-brown surface. A few small bits of black chert and pebbles of dark slate have also been found in the conglomerate.

Most of the pebbles of the formation are considerably rounded and worn. This is especially true of the large bowlders, many of which are four to six feet in diameter, a few are ten

feet, and one, 3.5 miles north of St. Albans, is even 60 feet long. This bowlder is surrounded by conglomerate except where the base is concealed for five feet, and various layers in the conglomerate about directly against its blunt ends. An obscure and distorted layering in the bowlder, which is of massive bluish-white limestone, dips about 70 degrees to the southeast, while the conglomerate dips 10 degrees southeast, and trends northeast instead of almost north like the conglomerate bedding. The bowlder is 60 feet long, 15 feet high, and 20 feet wide east and west. Most of the large bowlders are of blue limestone, but some are of the bluish-white marble, and in a few localities north of St. Albans, large reddish-brown dolomite bowlders form much of the conglomerate. The smaller pebbles are of all sizes and shapes down to fine sand. It is suggested by Sayles that a lenticular mass of blue limestone 140 feet long and 15 feet thick at the Corliss Ledge is a bowlder, like many smaller masses of the same kind of limestone. This is discussed under "Shelburne marble."

A peculiar but very common set of pebbles is composed of flat, angular slabs of blue limestone an inch or two thick and in many places more than a foot long. These are sharply angular and evidently have not been carried far from their original formation. About two miles northeast of Highgate Falls the source of these flat limestone slabs is seen to be the limestone layers in the Upper Cambrian Highgate slate. Fossils are numerous in these limestones in Highgate, but none has yet been found there in the pebbles of conglomerate, owing to the difficulty of separating the pebbles from the matrix. At many points, for instance, west of Georgia, Lower Cambrian fossils have been found in the smaller pebbles of the conglomerate.

The pebbles of gray sandstone and sandy dolomite are usually rather angular and have exactly the same characteristics as numerous beds in the Milton dolomite and Colchester formation of the Lower Cambrian. The peculiar dolomite pebbles with reddish-brown surfaces are duplicated in beds of the Colchester formation and Mallett dolomite. The source of the bowlders and round pebbles of blue limestone and marble cannot be so definitely ascertained. As already suggested, sources that are adequate and contain rocks of the same kind, are found in the Shelburne marble and the Williston limestone, a few miles south of the present end of the Georgia slate. The probability of this source is greatly increased by the discovery in Brandon of "Saratogan" cephalopods and in South Burlington of "Saratogan" trilobites and gastropods like those in the bowlders of the Swanton conglomerate.

Closely associated with the limestone conglomerates are beds of gray, sandy limestone and calcareous sandstone. These are from a few inches up to eight or ten feet thick and show occasional passages into quartzite. In them occur fragments of trilobites too small to name, but they show that the conglomerate was marine laid. As a rule the sandstones are above the conglomerates, but in some places they are interbedded or even at the base of the conglomerate. These sandstones are not distinguishable from similar beds in the Milton and Colchester formations and probably were derived from the same source, and even from the erosion of the Milton and Colchester themselves. A few layers of calcareous and argillaceous slate are found interbedded with the sandstones and conglomerates. A notable feature of the sandstones is the rather common inclusion of small pebbles of dark slate. These are angular and of the same character as the Highgate slates.

In a few places massive limestones form considerable bodies in the conglomerate. Notable among these is one at the Corliss Ledge, described below, where a lenticular mass of light blue limestone has a length of 140 feet and a thickness of 15 feet. It has been suggested that this mass is a bowlder in the conglomerate, but its dimensions are such that it could hardly stand transportation; yet another mass 60 feet long described above is almost certainly a bowlder.

Nearly five miles northeast of St. Albans, at the Corliss Ledge in the township of Swanton, numerous fossils were found in the conglomerate in September, 1921, by Dr. A. C. Swinnerton and the writer. These are of great importance in that they determine the Swanton conglomerate and the overlying sandstone and the slate beds of the Georgia to be of post-"Saratogan" age instead of Lower Cambrian, as long understood. The preliminary identification of the fossils and the conclusion as to their age were made by Schuchert, who had previously visited that general region in company wtih the author. Later the fossils were examined by Walcott, who also considers them to be of "Saratogan" age. One collection of the fossils, consisting of cephalopods, a brachiopod, a gastropod, and crinoid columnals, was found in a series of bowlders of blue limestone. These bowlders are squeezed and of lenticular shape, are underlain and overlain by conglomerate, and resemble a layer in that they occupy a horizon from one to two feet above the Highgate slate and a little more than 200 feet long. A second collection, consisting almost entirely of brachiopods, was made from a bluish-gray limestone bowlder about 100 feet south of the other fossiliferous bowlders. The bluish-gray limestone is almost a foot thick, rests directly on the Highgate slate, but is only exposed for a few feet along the strike. Other and similar limestone bowlders contained no fossils. The dip of the conglomerates and sandstones at this locality is about 20 degrees or less to the east, where they rest upon the Highgate slate, and their total thickness is about 30 feet. It was the good fortune of the writer, in company with Dr. Schuchert, to find in Brandon in July, 1922, blue limestones of the same kind

as the bowlders at Corliss Ledge and containing the same cephalopods, of "Saratogan" age. In September, 1922, Schuchert and Dunbar found "Saratogan" trilobites and gastropods in the same formation in South Burlington. In October, 1922, the writer found at the Marye Ledge (2 miles S. 30° W. of St. Albans) a bowlder of blue limestone in the conglomerate containing *Lingulella* and trilobites of late Upper Cambrian or "Saratogan" age, according to Schuchert. A nine-foot bowlder of Cryptozoön-bearing blue limestone, probably Beekmantown, was also found. The conglomerate here also contains many bowlders of white marble up to five feet in length, which are plainly derived from the Shelburne marble.

These fossils demonstrate a great unconformity below the Swanton conglomerate, which directly underlies the Georgia slate. In places, as already mentioned at Highgate, the Swanton conglomerate rests directly upon the Upper Cambrian Highgate slate. In Georgia the conglomerate is close to the Lower Cambrian Colchester formation and contains Lower Cambrian fossiliferous pebbles. In St. Albans the conglomerate rests upon and contains bowlders of the Lower Cambrian Mallett dolomite. The whole of the Shelburne marble and Williston limestone were removed before the Swanton was laid down. In other localities the unconformity at the base of the conglomerate is even more strongly brought out. Beginning three miles northwest of St. Albans, and continuing for ten miles southward along the strike, the Georgia slate, underlain by lenses of Swanton conglomerate in places, overlaps and is in contact successively with the Highgate slate, Milton dolomite, Colchester formation, and Mallett dolomite. These missing beds have a total thickness of 1,500 feet, and the Georgia slate cuts across them three times in that distance, so that the erosion preceding the Swanton was long and decided, and the relief of the pre-Swanton surface was considerable. Bowlders of amygdaloidal diabase and diorite are described by Logan from limestone conglomerates near Levis, Quebec, Canada, which are older (*i. e.,* Beekmantown) than the Swanton conglomerate. It, therefore, appears that the erosion surface had reached down even to the base of the Lower Cambrian, where there are bodies of such diabase and diorite.

Georgia slate.—The Georgia slate lies in a belt 34 miles long whose southern end is in Colchester and northern end in Highgate. North of the main belt there are several narrow strips of the formation extending to Canada, and several prongs of the slate project from the main formation in the vicinity of St. Albans. In the town of Georgia, for which the formation is named, the belt is at its widest—about three miles—and narrows to the north and south. Georgia Center is 20 miles south of Canada and 17 miles nearly north of Burlington. The map shows the general distribution of the slate, but it is possible that small areas of other slates are included in the general area.

The formation consists almost entirely of slate, as a rule, of a dark gray or bluish-gray color. Much of it is banded, a character which is easily seen on the weathered outcrops, which are apt to show a whitish surface. At the base of the formation lie several specialized and very important beds, chief of which is the Swanton conglomerate, which has been separated as a distinct formation. It is possible that there are other and higher conglomerates, but all now known are explainable as basal beds. The slates are soft and occupy low ground except in the town of Milton, where they rise sharply in Cobble Hill over 500 feet above the valley. At that locality the slates seem more siliceous than elsewhere, but otherwise differ little from the average.

The lentil described by Walcott as forming the middle of his "Georgia formation" proves to be part of the underlying Milton dolomite thrust up on a fault and locally capped by the Swanton conglomerate. At this point, about a mile nearly west of Georgia Center, there are remarkably fine exposures of the Swanton conglomerate and of its relations to the Milton dolomite. The Georgia-Milton contact is also exposed at that locality, where the intervening Highgate slate appears to be cut out in places by erosion. Only two exposures of the Georgia-Swanton contact are yet known, although in many places the two formations are separated by only a few feet, and are conformable in dip.

The Georgia slate lies in synclines, and its upper part has been removed by faulting or erosion. Its original thickness is, therefore, unknown, and even that of the portion remaining can only be estimated. There are no continuous sections of any considerable part of the formation, and the cleavage and variable dips of the slate make measures untrustworthy. In Georgia the slate forms a belt three miles wide, and its thickness is likely to be over rather than under 2,000 feet. Hitchcock considered the slate to be 3,000 feet thick and Walcott assigned to it a thickness of 3,500 feet or more.

The beds named Georgia slate have been studied for one hundred years and assigned to many different horizons. Their earliest appellation, "Primitive Argillaceous slate," was given them by Chester Dewey in 1824. From 1840 to 1860 Emmons assigned them to his Taconic system, lying beneath the "Silurian." In 1847, and until 1861, James Hall called them "Hudson River group" or "Lorraine shales (Silurian)." Logan considered them in 1859 and later to be of the age of the "Hudson River group" or even younger. Edward and C. H. Hitchcock in 1861 called them "Hudson River group (Silurian)." Thus the issue as to their age—"Silurian" or pre-Silurian—was early joined, and it was vigorously contested. The beds were definitely excluded from the Silurian by Billings in 1861, on the basis of fossils found by G. M. Hall and J. D. Perry, and were assigned to the Potsdam horizon. These fossils were shown later by Walcott to be of Lower Cambrian age, and in the work by the present author they have been found to come, not from the Georgia slate, but from the Colchester formation and underlying beds of the "Red Sandrock."

In 1861 in his original use of the term Georgia slate, Hitchcock included only the slates of Georgia and their supposed equivalents elsewhere. This usage was followed in the main by other geologists. The underlying limestones and sandstones were treated as another formation—the "Red Sandrock." In 1881 Marcou applied the term Georgia only to a narrow belt of slate passing through the Parker quarry in Georgia and called the main body of Georgia slate the "St. Albans group," all being assigned to the upper part of the Taconic system of Emmons. In this "group" were included numerous masses of limestones (called Swanton conglomerate in this paper) and of white quartzite (Cheshire) to which he applied the term "lentils." In 1884 C. H. Hitchcock and Whitfield called the Georgia slate Potsdam and Cambrian. In 1886 Walcott used the name Georgia both for the "Georgia shales" and for a larger "Georgia formation" which included the slate and the underlying beds, the Highgate slate, Colchester formation, Milton dolomite, and Winooski marble of this paper. All these beds he stated to be of Middle Cambrian age, as he had not then determined the true position of the Olenellus fauna which they contained. Later, in 1891, Walcott used the term Georgia as a series name for the Lower Cambrian, basing it upon the Georgia section. There has been considerable use of the term in this sense, but in 1912, on account of the varied usage of the name, it was given up by Walcott in favor of Waucoban, a name derived from California. In the present paper the formation is somewhat restricted from Hitchcock's original limits by cutting off about 300 feet of beds (Highgate slate) from the base of the formation, because they are of Upper Cambrian age, while the bulk of the Georgia slate is post-"Saratogan," and because there are between the two parts two great unconformities, as described under Colchester formation and Swanton conglomerate.

The fossils found in 1921 in the Swanton conglomerate underlying the Georgia slate showed it to be of post-Potsdam age instead of Lower Cambrian, as long supposed. How much younger than Potsdam the slate was could not be determined then, as in the few contacts known the slate appeared to lie conformably on the conglomerate. Its precise age was not determined until September, 1922, when two localities were found in Highgate which settled the matter. At the Oliver Grandge farm, 4.5 miles N. 10 E. of Highgate Center and .5 mile from the Canada border, the slate was found by the author on September 19, lying unconformably on the Highgate slate and separated from it by only a little lense of Swanton conglomerate. The gray, slightly sandy slate of the Georgia cuts out 2 feet of the Highgate slabby limestones, the two formations dipping easterly from 10 to 15 degrees. In the Georgia slate, 30 feet above the Highgate, Upper Cambrian fossils were found in several small masses resembling squeezed bowlders of öolitic limestone. The fossils were fragments of trilobites, brachiopods, tiny gastropods and cystid columnals. On the following day fossils were found by Schuchert in gray slate of the Georgian formation that rested immediately on the banded limestone and slate of the Highgate. On September 21, the author found another locality, a mile S. 20 E. of the above, where substantially the same fauna but of other species was more plentiful, especially the trilobites, in arenaceous limestone layers in gray slate. The fossils from these localities, according to the field determination by Schuchert, were at least as young as Black River and possibly as young as Trenton. More thorough examination in the laboratory will determine the age of the fossils with precision.

These fossils enable us to correlate the Georgia slate with the general period of shale deposition in the Hudson valley during the Middle Ordovician. Since the Georgia slate rests on the Upper and Lower Cambrian and nowhere on Chazy, Beekmantown, or "Saratogan," the great taxonomic importance of the erosion and later eastward overlap thus brought out is very apparent. A similar relation holds in Piedmont, Virginia, and it has long been the author's opinion that the eastward tilting at that time was one of the important Appalachian movements.

EASTERN SEQUENCE.

Cheshire quartzite.—This is the basal formation of the Lower Cambrian in Vermont and Massachusetts, and rests upon many formations of the pre-Cambrian. In northwestern Vermont the pre-Cambrian beds are usually phyllites with underlying dolomite and greywacke, all of probable Algonkian age. In southern Vermont older gneisses and granitic dioritic rocks of probable Archean age are in contact with the Cheshire quartzite. The formation is nearly continuous along the west foot of the Green Mountains throughout the length of Vermont. In the vicinity of Rutland, half-way north through the State, the quartzite is cut out along thrust faults for twelve miles, and the same is true for a stretch of about 15 miles south of Colchester. The formation was named from its exposures in the town of Cheshire, Massachusetts, not far from the south border of Vermont.

The formation consists mainly of clear white quartzite, with a central portion about 100 feet thick in which beds of dark gray or blackish phyllite are numerous. At the base there is in most localities a thin zone of conglomerate, rarely more than 10 feet thick. The formation varies considerably in thickness, being thickest in the middle portion of its course through Vermont and

thinner to the north and south. A good measure of the formation in Wallingford, sixteen miles south of Rutland, gives 800 feet of massive quartzite. In the section at Bristol the quartzite appears to be over 1,000 feet thick, but the lower portion and the base are not well exposed

Except in the conglomerates at the base the sand grains of the quartzite are very fine and evenly sorted. The most of the quartzite beds are massive, have a marked conchoidal fracture and very little bedding, and are from one to three feet thick. This is especially true of the uppermost beds, where it is often impossible to determine the bedding. Cross-bedding is occasionally seen in the quartzites, usually in the lower part of the formation, but as a rule the formation is devoid of structures other than ordinary bedding. In the central part of the formation beds of phyllite and slaty banded sandstones alternate in layers of an inch to two feet in thickness and form perhaps half of the strata for 100 feet in thickness. These are well seen in Forestdale, three miles northeast of Brandon, and 14 miles southeast of Middlebury.

The basal conglomerate usually consists of white and blue quartz pebbles an inch or less in diameter, closely sprinkled through a siliceous matrix. In places the pebbles are much coarser, and bowlders as much as three feet in diameter are known. These large bowlders, as well as most of the others, are of white quartz. In the coarse conglomerates there are also scattered pebbles of feldspar and quartzite, and, in a few cases, of fine granite. The best exposure of this type of the conglomerate is in Chittenden, ten miles east of north from Rutland. The source of the conglomerate pebbles seems to be in all cases the various formations of the pre-Cambrian. There is a considerable calcareous element in the conglomerate where it rests upon the Algonkian dolomite, about ten miles southeast of Middlebury and near Lake Dunmore. At this point the conglomeratic base of the formation is shown in the bed of Sucker Brook resting on an eroded surface of Algonkian dolomite.

In most places the quartzite is sharply defined from the overlying Rutland dolomite, and not infrequently the entire change from clean, vitreous quartzite to pure, gray dolomite is accomplished in five or six inches. In a few places, for instance, five miles north of Rutland on the south slopes of Blueberry Mountain, there is a transition upward from a vitreous quartzite through calcareous quartzites and sandstones and interbedded dolomite beds for about 50 feet.

A few fossils have been found in this formation, most of them by Walcott, at several points from Lake Dunmore near Middlebury southward to Massachusetts. Fossils were also found by Wolff near Rutland. All of the fossils in the formation have been determined by Walcott to be of Lower Cambrian age.

The formation appears to be equivalent in age with the Monkton quartzite, but deposited under different conditions and in a different bathymetric zone, as will be discussed under "Sedimentation."

Rutland dolomite.—This formation lies along the eastern margin of the Champlain valley and its southern extension between the Taconic range and the Green Mountains. It is practically coextensive with the preceding Cheshire quartzite and is cut out by faults between Colchester and Hinesburg, like the Cheshire quartzite. It is very well developed in the valley around Rutland and receives its names from that place.

The formation consists mainly of dolomite, generally of a gray color. Beds of a dark bluish-gray dolomite are numerous in the lower and upper parts of the formation, while light and dark gray layers are found throughout its thickness. A few light buff, almost white, beds of limestone are found in the upper part of the formation just north of Rutland, and a few layers of blue limestone are scattered at various horizons through the formation. The interbedded sandstones at the base of the formation have already been described; such beds are rare at other horizons. Most beds in this formation are fine-grained, but here and there medium-grained dolomites and a few coarse layers are found. The coarse-grained beds are not otherwise different from those of fine grain, and there seems to be no predominance of coarse grain at any horizon. Here and there the dolomites, especially the coarser-grained ones, contain scattered nodules or geodes of vein quartz of small size. In the town of Monkton the base of the formation consists of a few feet of fine dolomite of a light buff or cream color, more or less mottled with pink. These beds appear to be representative of the pink mottled Winooski marble which farther west in the same town overlies the Monkton quartzite. The two formations are now in contact, having been brought together on the Weybridge fault.

Fossils have been found in numerous parts of the Rutland dolomite. Most of them were discovered by Wolff at various horizons in the township of Rutland and were determined by Foerste to be of Lower Cambrian age. The formation is equivalent to the combined Winooski marble and Mallett dolomite of the central sequence, since they rest upon the quartzites of the same age and are followed by the same strata. The Rutland dolomite is probably in the vicinity of 1,000 feet in thickness; there are no continuous sections of the formation, however, and the full content of the formation has to be built up from scattered sections.

Colchester (?) formation.—Beds of Colchester age appear in the eastern sequence in the town of Hinesburg and are found southward to Massachusetts, with many interruptions due to folding and faulting. These beds in the towns of Monkton and Starksboro, adjoining Monkton on the east, have the same characteristics as the Colchester formation from Monkton northward. Toward the south, however, in the towns of New Haven and Middlebury, beds of light buff dolomite weathering with a rusty brown or tan colored surface come into the formation. The gray dolomite and dolomitic sandstone or quartzite characteristic of the Colchester continue well marked toward the south. As a whole, the formation thickens considerably to the south.

A conclusion has not been reached as to the advisability of a separate name for the beds of this age in the two sequences. The beds overlying the Colchester formation in its southward extension are of practically the same character as the Milton dolomite and will not be described here in detail. The overlying dolomite contains none of the chert so common in the Milton, but the marbles and limestones closely resemble the Shelburne and Williston formations.

WESTERN SEQUENCE.

Potsdam quartzite.—Strictly speaking, the Potsdam beds of the western sequence do not outcrop in the area here discussed in detail, which extends from Canada southward to Middlebury. Potsdam rocks, however, are found in the town of Shoreham, about 15 miles southwest of Middlebury, and just west of the Champlain fault in Snake Mountain. The Potsdam here is limited to small areas with a maximum length of four or five miles and less than a mile wide. The Potsdam rocks of this locality differ little from those of the well-known Potsdam areas around the east flank of the Adirondacks. They consist of fine-grained, white quartzite composed almost wholly of rounded quartz grains, and are somewhat calcareous at the top. The quartzite beds closely resemble those of the Cheshire quartzite, except that they lie in thinner layers, so that the bedding is more distinct. The calcareous quartzite at the top of the Potsdam is, however, like many calcareous dolomitic sandstones in the Swanton and Georgia formations and also in many Lower Cambrian horizons. The base of the formation is not exposed, since it appears on anticlines more or less faulted. The full thickness of the formation is not known, but probably 300 feet are exposed. No description will be given here of the overlying Ordovician rocks, the Beekmantown, Chazy and Trenton limestones, and the black slate of Trenton age.

HISTORICAL GEOLOGY.

SEDIMENTATION.

Deposition cycles.—The Cambrian rocks of this region were deposited in an order or cycle, which is often to be seen in other regions as well, consisting of a basal conglomerate, quartzite, carbonate rocks (mainly dolomite), limestone, and shale. This is a very common response to the environment of a deepening sea and a later uprising land, which in turn are the expression of warping of the crust of the earth. This cycle is manifest in each of the three sequences of this region, the main difference being that the western cycle begins with the Potsdam of younger age, while the cycles of the central and eastern sequences are mainly in the Lower Cambrian. In each sequence the proportion of land waste is at first extremely high, changes abruptly to a minor element at the end of the quartzites, rises to a majority in the middle of the section, descends to little or nothing in the upper dolomites, and sharply increases with the incoming shale.

Lower Cambrian.—The expansion of the sea which permitted the Lower Cambrian sediments to be deposited affected the entire length of the Appalachians—over 1,500 miles on the mainland of North America—but only in a narrow belt. Previous to this movement all the eastern part of the continent was land, and erosion had cut widely and deep into or even through the Algonkian sediments. The basal deposits of the Cambrian extended far to the east of the Lake Champlain region and even of the Green Mountain area, but are not present around the Adirondacks. The westward overlap of the Lower Cambrian is thus very extensive and cuts out a large series, whose thickness of about 2,000 feet gives a minimum measure of the trough. This overlap is one of the most important in the Appalachians and is a fitting beginning for the Paleozoic.

Land lay near at hand in the Adirondack region and its extension of those days to the north and south. This was the most important land axis of the early Paleozoic and persisted with diminishing strength well through the Paleozoic. East of this lay the Lower Cambrian sea, its western margin directly in this area and its eastern shore at a considerable but unknown distance east of the Green Mountains.

The position of the strand in this region is well shown by the Monkton quartzite, whose red muds and sands give plain evidence of subaerial deposition, and whose occasional marine fossils show incursions of the sea. At the same time the clean, sorted sands of the Cheshire quartzite with a few marine fossils were originally deposited many miles farther east under the clean sea water. The same story is told by the great thickness of these sands along the Green Mountain front and their thinning to the east, where they can be traced across the Green Mountains east of Rutland and around them at the border of Massachusetts.

A similar plan of land and sea is recorded in the Winooski marble, especially in its topmost quartzite layers which duplicate the Monkton. By later formations, the Mallett and Colchester, deeper waters are shown, but terrigenous beds are numerous, and intraformational conglomerates show that the sea waters were very shallow from time to time and that there was even strong erosion and local removal of the Mallett dolomite. At the end of the Colchester formation the land was uplifted and subaerial erosion of this region began. Much of the Lower Cambrian sediment was swept away, and a surface of considerable relief was produced, the erosion being deepest at the north and west. Whether this took place in Middle or Upper Cambrian time can not at present be shown. No beds of Middle Cambrian age in place are as yet certainly known, and it is most reasonable, therefore, to assign the erosion to that epoch.

Between the movements which began and ended the Lower Cambrian cycle there were several minor oscillations recorded in the intraformational conglomerates due to more active erosion. The principal ones of these are at the top of the Winooski marble and at the base of the Colchester shale, which are of only shale value. The sandstones of which so many are found in the Mallett dolomite also give evidence of changes of the land, probably due in some degree to tilting.

Middle Cambrian.—Deposits of Middle Cambrian time are not known in this region, unless perhaps the Milton dolomite is in its lower part of that age, or unless the upper part of the Colchester formation is Middle Cambrian. With these possible exceptions the land was raised during that epoch and subjected to continuous erosion. The nearest Middle Cambrian sediments are in eastern Massachusetts.

Upper Cambrian.—The conglomerates which began and characterized Milton sedimentation extended 50 miles in Vermont and with their considerable thickness give evidence of important movement, though possibly limited to northern Vermont and adjoining Canada. Erosion was active, whether by streams or by glaciers. The resemblance of the conglomerates and breccias to tillite is stronger in the upper beds and is pronounced in the topmost or giant conglomerate at Highgate Falls. Depression of the land again changed the scene, and an influx of muddy water produced the Highgate slate. The fine banding of this formation is strongly suggestive of glacial seasonal banding. This suggestion that glaciers were present near this region is apparently lent support by the adjoining conglomerates and breccias of the Milton, which are decidedly angular and unsorted and resemble tillite. While neither of these formations alone furnishes complete proof of a glacial origin, in combination they render the hypothesis attractive. In short, the rocks of that time indicate a situation closely parallel to the Pleistocene glacial epoch, with its till, sand, and banded clay in the same region. If the Highgate and the conglomerate zone of the Milton represent a glacial epoch, the land high enough to support glaciers doubtless lay at the north and west, as it had in previous Cambrian time.

In northern-central Vermont and adjoining Canada Cambrian deposits have been reported. No fossils have been found in them, however, and their assignment to the Cambrian rests on their relation to limestones and slates which carry fossils of reputed Ordovician age. The supposed Cambrian beds are reported by Richardson to underlie the Ordovician strata. If that is the case, they are more likely to be Lower than Upper Cambrian, since the extension of the Lower Cambrian was eastward across Vermont, while the Upper Cambrian and "Saratogan" waters extended mainly westward. There are no known Cambrian rocks east of Vermont nearer than Braintree and Attleboro in eastern Massachusetts. The beds in Braintree are Middle Cambrian and those of Attleboro Lower Cambrian. Thus, the eastern extent of the Cambrian of Vermont is conjectural. The only known Ordovician beds east of the Green Mountains are the graptolite-bearing limestones of northern-central Vermont, described by Richardson. Silurian and Devonian beds are known near Connecticut River at several localities, and underlying them are strata assigned to the Ordovician on the basis of this position. These facts seem to indicate that there is only a small extension of the Ordovician and also of the Upper Cambrian eastward from the Green Mountains.

"Saratogan."—"Saratogan" deposition produced in this region the Williston limestone and perhaps the Shelburne marble. Other deposits of this time are not known in this district but are found about 15 miles southwest of Middlebury in the town of Shoreham. In that area the Potsdam quartzite forms many outcrops, while many more areas of the formation are found not far to the west along the flanks of the Adirondacks. Still farther to the west and south "Saratogan" deposits are spread over many States. The cycle of deposition which began with the Potsdam for areas west of the Snake Mountain fault is not manifested elsewhere in northwestern Vermont. The physical relation between the Potsdam and the Williston is not known, and they are probably not exactly equivalent. In view, however, of the great westward tilting of the crust at this time, it is probable that the Williston was a slightly earlier deposit than the Potsdam as the sea spread westward. The waters of the Potsdam time and even of the Ordovician epochs were not deep enough, however, to cover certain high parts of the Adirondack land.

Middle Ordovician.—Uplift ended the "Saratogan" deposition, and the erosion cut long and deeply into its strata. When the sea advanced again it found an irregular topography, and the first beds of the Ordovician (Swanton conglomerate) were irregularly distributed. The peculiar nature of the Swanton conglomerate has long since raised the question of its origin. Walcott, reasoning from the fact that most of the pebbles could be duplicated in the Lower Cambrian formations of the region, established it as the type of intraformational conglomerate, and considered that most of the pebbles were broken up from the parent rock soon after its formation and were deposited with little transportation. Since, however, the conglomerate contains Lower and Upper Cambrian and "Saratogan" fossils in the pebbles, it can not be intraformational. Its position resting on the Lower and Upper Cambrian establishes it as a basal conglomerate following an unconformity.

The discovery of its true position does not, however, explain such features as the total lack of sorting of the fragments, which include bowlders 10 and perhaps 170 feet in length, mere sand grains, and fine calcareous mud side by side. Furthermore, equally in contrast are the rounding of the large bowlders and the sharp angles of flat limestone slabs. The pebbles also contain samples of beds that do not outcrop within miles, these being the most worn, while others of local origin are sharp angled. The amount of transportation shown by these extremes differs enormously and shows some agent differing from ordinary streams. The obvious suggestion is that glacial action was involved in the transfer and accumulation of the deposit. This idea is given support by the considerable assortment of kinds of pebbles, the distant origin of some, and the local sources of others. The position of the fragments is rather random, as in a tillite, although such a relation has been obscured by the squeezing and folding of the rocks.

Still further support is given to the hypothesis by the banded character of the Georgia slate which followed the conglomerate. Much of this formation is uniform and uniformly banded, like the marine glacial clays of the Pleistocene in the same region. In short, the Swanton-Georgia sequence is a close duplicate of the Pleistocene till-clay sequence. The principal difference is that the Pleistocene beds contain more of the far travelled bowlders than the Swanton, a difference attributable, perhaps, to a more local origin of the Ordovician glaciers. Although the glacial origin of the conglomerate and slate is only a hypothesis, it is reasonable and well worthy of consideration. If the conglomerate is a tillite, it is in part submarine because the accompanying sandstones contain trilobite fragments.

DEFORMATION.

Pre-Cambrian disturbances.—The earth's crust in this region has often been deformed, sometimes by mere oscillations up and down and sometimes by revolutions which crushed and upset all previous structures. Earliest of all of which there is record was the intrusion of granite and similar rocks into pre-Cambrian basement rocks. In pre-Cambrian time there was also enormous compression, folding, and mashing of the rocks, by which processes were formed the gneisses and schists. Whether or not granite intrusions accompanied this deformation there is no proof at present, but some intrusions were Archean and older, while others were later and cut the Algonkian rocks. The forces that drove these great masses of molten matter into the Algonkian sediments were enormous and inevitably distorted the crust from its previous attitude. A general uplift of land resulted from these movements, and sediments laid down under water were exposed and deeply worn.

Lower Cambrian warping.—A reverse movement of depression began the sedimentation of Lower Cambrian time. This was of a broad regional nature with a moderate amount of tilting, but no compression sufficient to shorten the earth's crust in this region. The depression went on until about 2,000 feet of sediment were deposited, which gives a minimum measure of the warping. A local reversal and uplift near the end of the Lower Cambrian caused the erosion of over 600 feet of the Mallett dolomite.

Middle Cambrian warping.—Oscillations of this kind—broad up or down movements with some tilting—recurred at several times during the Cambrian. The most important took place during or just after the Middle Cambrian, as already described.

"Saratogan" movements.—The tilting and submergence that initiated "Saratogan" sedimentation were of similarly great importance, and vast areas of eastern America received deposits of the Paleozoic sea for the first time. The submergence of broad areas west of the Lower Cambrian trough and erosion at the east indicates that the uplift was at the east and the depression to the west. Thus was reversed the arrangement that prevailed during Lower Cambrian time, and a new distribution of the lands was begun which prevailed in a large way through the rest of the Paleozoic era, except for the submergence in the Middle Ordovician.

Middle Ordovician.—The Georgia slate, and the Swanton conglomerate where present, rest on two formations of the Lower Cambrian, and two of Upper Cambrian age, and contain bowlders of at least one "Saratogan" formation. The erosion into and through these formations is so considerable that we must conclude that there was important tilting and perhaps even some folding, in order that beds so widely separated should be brought to the same surface of erosion. The indication is clear that the changes that followed the "Saratogan" in this region were of the order in diastrophism that usually is associated with the breaks between systems. This has a decided bearing on the Ozarkian system proposed by Ulrich, by showing a great physical break between it and the Ordovician. In this region the uplift and erosion following the "Saratogan" continued until the Middle Ordovician. Beekmantown and Chazy beds are common west of the Champlain fault and are overridden by the Cambrian on the fault. They do not, however, appear east of the fault and

north of Middlebury, although the younger Georgia slate is present. These facts suggest that the first uplift from which the fault later developed began between the "Saratogan" and the Beekmantown. Thus the gap after the "Saratogan" is measured by non-deposition of two large formations and erosion into and through six other formations.

Appalachian Revolution.—Many subsequent oscillations no doubt took place here, as in adjoining regions. The late Devonian folding that affected New Brunswick and Maine so strongly appeared only as uplift in western New England. No trace of it is seen between Connecticut River and the Catskills except in greatly increased sedimentation, nor does any record remain of any movements after the Middle Ordovician until the great deformation which closed the Paleozoic. This is shown here on a grand scale, with all the features which characterize the Appalachian revolution. Long, closed, and overturned folds and thrust faults both folded, faulted and simple, are numerous, and the shortening of the crust in the narrow Champlain valley is enormous. Over large areas the forces and the reactions were so tremendous that the strength of the rocks was entirely overcome. The minerals were recrystallized, beds flowed or were torn apart and the aspect of the rocks was very greatly changed. The faults record two periods of thrusting, separated by an unknown interval of time. East of the Green Mountains great masses of granite were forced into the sedimentary rocks. The crust of the earth was jammed and piled up, and its surface rose above the sea. As it rose it began to wear away, but the uplift exceeded the waste, and no doubt great mountains were formed.

Triassic faulting.—The next structural event of record is the normal faulting exhibited near the shores of Lake Champlain. The youngest beds cut by these faults are of Middle Ordovician age, so that by that criterion they cannot be separated from the thrust faults, which cut the same rocks. However, the physical incompatibility of these faults—the results of extension of the beds—with the extreme compression of the Appalachian Revolution compels an assignment of them to a date after the compressive strains were satisfied or transferred to other parts of the earth. Furthermore, there is a decided difference in trend between the two fault groups. So far, no normal fault has been found cutting the thrust faults, but the two sets adjoin so closely that probably such a relation will be found. The period which seems most likely for the formation of the normal faults is the Triassic. Everywhere in eastern America the Triassic period was closed by uplift with normal faulting, and no other period of normal faulting is known in the Appalachians. Some of the Triassic faults can be traced from the Triassic belt of New York into districts near to this. Accordingly, the reference of the normal faults of this region to the Triassic is reasonable.

Cretaceous (?) fissuring.—Scattered over western Vermont and adjoining areas are numerous dikes of camptonite and similar rocks. These have a marked trend a little north of west and nearly vertical attitudes, and they are seldom over eight or ten feet wide or an eighth of a mile long. Evidently these dike rocks were forced when molten into a set of fissures which were formed by a regional strain. The regularity of the fissure trends indicates a corresponding simple tension in a nearly north-south direction. The lack of displacement on these fissures also indicates the simplicity of the strain. Whether the body of molten rock pressing upward furnished the tension at the surface or simply availed itself of channels already formed by other forces cannot yet be determined. If the pressure of the magma were the cause, the uniform plan of the fissures in only one direction seems much less likely than a more random or varied plan. There is neither direct evidence of the age of these dikes, nor are similar sets known in adjacent regions. They are entirely different from the Triassic types, and they are unmetamorphosed, so that they are post-Carboniferous. On general grounds, it seems most likely that they are of Cretaceous age.

Post-Triassic oscillations.—The movements of the earth thus far discussed are shown by the overlap, folding, or displacement of the rocks. Subsequent movements there were at many epochs, but their effects cannot be disentangled from far greater changes already wrought upon the rocks. The forms of the land tell their story, however, and later uplifts and pauses are recorded at many epochs from the Cretaceous down to the present. The pauses are deduced from the plains formed nearly at sea-level during a long stand of the land in one attitude, and the uplifts are evidenced in the present heights of these old plains and their deep dissection by the streams into valleys and lower plains. At least seven of these pauses are known, with a corresponding number of uplifts. There doubtless were many depressions as well as uplifts, but there is no present means of determining any except the latest.

Glacial tilting.—One of the depressions accompanied the great invasion of glacial ice from the north, and the view is widely accepted that the weight of ice caused the crust to bend and settle. The reverse movement of uplift accompanied the disappearance of the ice, and the land nearly recovered from its great depression at the north. The tilt that it received in glacial time is now recorded in the inclined plains of glacial clay and sand and in the terraces and deltas which rimmed the margins of glacial water bodies.

NEW UPPER CAMBRIAN AND LOWER ORDOVICIAN TRILOBITES FROM VERMONT[1]

PERCY E. RAYMOND,

Harvard University.

INTRODUCTION.

The northwestern portion of Vermont has attracted the attention of scientific men for nearly a century. It has been the common ground of geologists and palaeontologists from Canada and the United States, and such familiar names as Logan, Billings, Hall, Marcou, and Walcott at once leap to mind when one thinks of this classic region. Needless to say, the structure of the area is not simple, and many diverse views have been held by the successive generations of geologists who have worked there.

Keith (1923) has at last, by careful areal mapping, been able to establish definitely the sequence of formations, and to locate the thrust faults which cause so much trouble. In the course of his work, he was constantly searching for fossils, and at his request, Professor Charles Schuchert accompanied him a part of the time. Lower Cambrian fossils have of course long been known from this region, and scattered references have been made to the presence of species of Upper Cambrian age. The most important discovery was made by Keith when studying the gorge at Highgate Falls, Vermont, in company with Professor Schuchert, Mr. R. W. Sayles, and Dr. Swinnerton. An abundance of Upper Cambrian fossils was then found in what Keith has named the Missisquoi formation,[2] in thinly bedded limestone associated with limestone conglomerates. In the following pages, the writer describes 45 species from this locality, 36 of which are new. The equivalent beds have not yet been found in place elsewhere.

The Missisquoi is overlain at Highgate Falls by the thinly bedded limestone and shale of the Highgate formation, which is

[1] Republished, by permission, from the Proceedings of the Boston Society of Natural History, Vol. 37, No. 4, pp. 389-466, Pls. 12-14. 1924. A few changes have been made in the text.

[2] Later work has shown that there was a considerable interval between the time of deposition of the dolomite to which the name Milton was applied in my previous paper (1923) and that of the thinly bedded limestone there called the Upper Milton. I, therefore, propose to call the latter the Missisquoi formation.—ARTHUR KEITH.

more or less well exposed to a number of places in the vicinity of Highgate Center. Because of the pressure which it has undergone, the Highgate has developed in it a schistosity which makes the collection of fossils very difficult. The present indications are that its fauna is limited in variety. The Georgia rests upon the Highgate, and although largely a slate, contains some limestone in which fossils are abundant, although distorted and very fragmentary. Brachiopods are much more common than trilobites at that horizon. A brief discussion of the faunas and their probable ages will be found in the summary at the end of the paper.

The greater part of the fossils here described were collected by Professor Schuchert, who visited these localities twice in 1922 and again in 1923. On the second trip in 1922 he was accompanied by Professor C. O. Dunbar, who made a part of the collection. At Professor Schuchert's request, the writer studied the trilobites during the winter of 1922-23, at which time nearly all of this paper was written, and in the summer of 1923, he visited all the localities and made additional collections.

Most of the types of the species described are in the Yale University Museum, but representative collections have been deposited in the Museum of Comparative Zoology, and the Museum of the Boston Society of Natural History. The figures for the plates were drawn by Dr. Elvira Wood, with the exception of figures 1, 2, 3, 4, 10, 16, 20 and 23, Plate 12; figures 10 and 12, Plate 13; and 4 and 20, Plate 14, which were done by Miss Krause of New Haven.

DESCRIPTION OF SPECIES.

Order HYPOPARIA Beecher.

Family AGNOSTIDAE McCoy.

Subfamily *Agnostinae* Jaekel.

Agnostus innocens Clark.

Pl. 12, figs. 1, 5.

Agnostus innocens CLARK, Canadian Field-Naturalist, Vol. 37, p. 121, Pl. 1, figs. 7, 7a, 1923.—Bull. Am. Palaeontology, 1924, Vol. 10, No. 41, p. 17, Pl. 3, figs. 3, 3a.—RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 390, Pl. 12, figs. 1, 5.

Description.—Cephalon (pygidium of modern authors) small, strongly convex, with narrow, flattened but still slightly convex border. Glabella wide, roughly parallel-sided, semicircular in outline at the front. It is crossed by two straight furrows, the anterior of which is at about the mid-length. The frontal lobe is as broad as long, gently and evenly convex. Both the posterior segments of the glabella are crossed by a pair of longitudinal furrows which break each into three nodes, the outer ones wider than the median one. The central node of the median segment rises into an elongate, ridge-like tubercle, whereas the others are low, smooth mounds. The pleural lobes are smooth. On either side of the margin there is a scarcely perceptible scale-like spine.

Pygidium of small size, strongly convex, with a narrow, flat border. Axial lobe wide at the anterior margin where the accessory lobes cause a sudden expansion; it tapers backward rather gradually behind these lobes. Two cross-furrows divide the axial lobe into three unequal parts. The anterior one is a high, nearly hemispherical mound, surmounted by a small tubercle. The median portion is short, depressed, flat on top, and produces a marked depression in the middle of the axial lobe. The hindermost part is ovoid, almost pointed behind, moderately convex, smooth. The dorsal furrows unite in a median furrow back of the axial lobe as usual in the genus, but this furrow is nearly filled by a low ridge.

Measurements.—Length of cephalon (plesiotype) 4 mm., width 4 mm.; length of glabella 3.5 mm.; width of frontal lobe 2 mm., length 2 mm. Length of pygidium (plesiotype) 6 mm., width 5 mm. (specimens somewhat compressed); length of axial lobe 4.5 mm.; width at accessory lobes 2.5 mm., at middle of posterior lobe 1.75 mm. Other individuals are smaller. The largest cephalon is 6 mm. long.

Comparisons.—As here described, the usual identification of cephalon and pygidium is reversed, although such a procedure cannot yet be fully justified. There is no other described American species of this type, and I have found no European species more like it than *Agnostus trisectus* Salter. That has the same subdivision of the posterior part of the glabella into six small lobes, but the frontal lobe is also trisected, and the cheeks are striated. The two species are probably not closely related.

Horizon and locality.—Both cephala and pygidia are common in zone 3 of the Missisquoi, and are associated for that reason. Clark described the species from specimens obtained in a boulder in the conglomerate at Lévis.

Holotype and paratype in the Museum of Comparative Zoology. Plesiotypes here figured are in Yale University Museum.

Agnostus trisectus Salter.

Pl. 12, fig. 3.

Agnostus trisectus SALTER, Mem. Geol. Surv., Brit. Org. Rem., Dec. 11, Pt. 1, p. 10, Pl. 1, fig. 11, 1864.—BELT, Geol. Mag., Dec. 1, Vol. 5, p. 11, 1868.—LINNARSSON, Sveriges Geol. Undersokning, Ser. C, No. 43, p. 157, Pl. 6, fig. 16, 1880.—TULLBERG, Sveriges Geol. Undersokning, Ser. C, No. 42, p. 24, Pl. 1, fig. 13 a, b, 1880.—MATTHEW, Trans. Roy. Soc. Canada, Vol. 11, Sect. 4, p. 110, 1893.—LAKE, Brit. Camb. Tril., p. 10, Pl. 1, fig. 15, 1906.—WESTERGARD, Sveriges Geol. Undersokning, Ser. Ca, No. 18, p. 117, Pl. 1, figs. 11, 12, 1922.

Agnostus princeps var. *ornatus* Salter, Mem. Geol. Surv., Brit. Org. Rem., Dec. 11, p. 4, Pl. 1, figs. 4, 5, 1864.

? *Agnostus trisectus* mut. *ponepunctus* MATTHEW, Bull. Nat. Hist. Soc. New Brunswick, Vol. 4, p. 278, Pl. 5, fig. 8a-c, 1901; Rept. Camb. Rocks of Cape Breton, Geol. Surv. Canada, 1903, p. 220, pl. 17, fig. 8a-c.

A single cephalon (pygidium) of this species was found by the writer in 1923. It is somewhat damaged on one side, but shows the characteristic ornamentation, and the peculiar tripartite longitudinal division of the entire axial lobe. The occurrence of the species in this fauna is of particular interest since it has been found to be characteristic of the Peltura zone on Cape Breton, in Great Britain, and in Sweden. Specimens from these widely separated regions show some differences, which may be found to be of specific value. Salter's figured specimen and that from Vermont show two continuous transverse furrows across the glabella, whereas on figured Swedish examples the posterior of these is interrupted by the median pustule. Lake states that both conditions obtain among British specimens. The somewhat obscure ornamentation of the specimens from Cape Breton may justify Matthew's varietal name.

Agnostus americanus Billings appears to be closely related to *Agnostus trisectus,* but has the anterior lobe of the glabella incompletely subdivided. The posterior trans-axial furrow does not cross the median tubercle, and the radial grooves on the cheeks are less deeply impressed than in European specimens of *Agnostus trisectus*.

Measurements.—The length of the cephalon of *Agnostus trisectus* from the Missisquoi is 3 mm., the greatest width about the same.

Horizon and locality.—From the main zone of the Missisquoi at Highgate Falls, Vermont. Figured specimen in the Museum of Comparative Zoology.

Agnostus insuetus Raymond.

Pl. 12, figs. 2, 6.

Agnostus insuetus RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 393, Pl. 12, figs. 2, 6.

Description.—Cephalon somewhat quadrangular, wider than long, with a wide, convex border from which project a pair of short antero-lateral spines. Glabella large, vaulted, and extending nearly to the anterior border. It is roughly rectangular, but the sides are somewhat concave. There are two pairs of glabellar furrows, the hinder ones narrow, directed diagonally inward, almost isolating the basal lobes. The second furrows are faint, and run directly inward on the sides of the middle of the glabella. An oval scar on the summit of the posterior third of the glabella indicates that a rather large median pustule was present. Fixed cheeks low, narrow, and connected around the front of the glabella by an extremely narrow ridge. On the left cheek is what has the

appearance of a vestigial facial suture. Starting in the middle of the anterior margin, it runs back in a gentle curve to the dorsal furrow, keeping just outside it to a point opposite the middle of the glabella. Thence it turns diagonally outward and backward toward the genal angle. The other cheek shows the anterior part of the suture quite clearly, but the posterior part is obscure. The sutures meet in a "Λ" (*en ogive*) at the front. Pygidium small, about as long as wide, very highly convex, and with a narrow flattened rim. Axial lobe highly convex, with small accessory lobes. It is crosssd by one transverse furrow, which divides it into two segments, the anterior twice as long as the other, and bearing on its summit a small conical tubercle. The dorsal furrows meet behind the axial lobe, but there is only the merest trace of such a median longitudinal furrow as is usally found on the pygidium in this genus.

Measurements.—Length of cephlon 2 mm., width 2.5 mm.; length of glabella 1.75 mm., width at back 1.5 mm., at front 1.25 mm.; length of pygidium 1.5 mm., width 1.75 mm.; length of axial lobe 1 mm., width of anterior segment 0.75 mm.

Comparisons.—This species is apparently closely allied to *Agnostus pisiformis obesus* Belt, or at least some of the species which pass under that name. Among specimens referred to that variety there are some with vestiges of a median furrow back of the axial lobe of the pygidium, and some with no trace of it. The present species differs from the British and Scandinavian specimens of *Agnostus obesus* (Lake, 1906, Pl. 1, figs. 13, 14; Westergard, 1922, Pl. 1, fig. 4-6) in having weaker second glabellar furrows and the median pustule farther back on the glabella. The presence of what appears to be a suture on this specimen, if the line is not accidental, is of great importance. It shows, first that what has in the past been called by most writers the pygidium is really the cephalon, and secondly, a fact of wider interest, that the Agnostidae are, as many writers have suggested, really degenerate trilobites which have secondarily achieved blindness. The suture is not close to the margin, as one would expect in a primitive trilobite in which the free cheeks were just appearing on the margin, but on the other hand, as close to the dorsal furrows as possible.

Horizon and locality.—This is a rare species found so far only in zone 3 of the Missisquoi at Highgate Falls, Vermont.

The types are in the Yale University Museum.

Pseudagnostus extumidus Raymond.

Pl. 12, fig. 7.

Pseudagnostus extumidus RAYMOND, Proc. Boston Soc. Nat. Hist., Vol. 37, No. 4, p. 394, Pl. 12, fig. 7.

Description.—Cephalon small, about as long as wide, reaching its greatest convexity near the posterior end. There is a relatively wide flattened border which is not set off by a sharply impressed furrow such as is usual in Agnostinae, and on either side there is a short spine. The glabella is wide, smooth, without furrows, and the broad shallow dorsal furrows are so lightly impressed that the outline is marked only by an obscure ridge encircling the convex portion of the cephalon. There is a small tubercle on the median line about one-third the distance from the back.

Measurements.—Length of cephalon (holotype) 2.5 mm., width 2.75 mm.; length of glabella 2 mm., with 1.25 mm.

Comparisons.—I have referred this species to Pseudagnostus, but it has more the appearance of a true Agnostus with cephalon "smoothed out." It differs from other species of Pseudagnostus in lacking a cross-furrow on the glabella, and in having the anterior end of the median lobe definitely, although faintly, outlined.

The collection contains three specimens of a pygidium which may belong to this species. It is longer than wide, has the features of the pygidium of Agnostus, but the dorsal and transverse furrows are very faint, so that the axial lobe almost merges into the general convexity. If cephalon and pygidium pertain to the same trilobite, a new genus must be made for their reception.

Horizon and locality.—Three specimens of the cephalon were found in zone 3 of the Missisquoi at Highgate Falls, Vermont. Two of the pygidia mentioned were found in the same zone, and one in zone 2.

The type is in the Yale University Museum.

Subfamily *Condylopyginae* Raymond.

Peronopsis planulata Raymond.

Pl. 12, fig. 9.

Peronopsis planulata RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 395, Pl. 12, fig. 9.

Description.—Known from pygidium only. Pygidium only moderately convex, with very shallow dorsal furrows, and a flat border, which is widest posteriorly. Axial lobe only slightly elevated, not sharply delimited, two-thirds the total length. There is a small median tubercle situated two-thirds the length of the median lobe behind the anterior margin. In front of it is a very faint transverse furrow, and behind it an obscure one passes obliquely backward to the dorsal furrow on either side, delimiting an obscurely pentagonal posterior portion of the lobe. There appear to be no anterior accessory lobes, although a furrow is suggested at one side.

Measurements.—The holotype (pygidium) is 3.25 mm. long and 3.00 mm. wide; the axial lobe is 2.00 mm. long and 1.75 mm. wide at the front.

Comparisons.—Although many species of Peronopsis are known, few if any have the parts so obscurely delimited as in the one here described. There is an extremely faint median depression at the posterior end of the axial lobe which suggests the bifurcation in that region which is so conspicuous a feature of *Peronopsis fissa* (Lundgren) and *Peronopsis planicauda* (Angelin). *Peronopsis interstricta* (White) is somewhat similar, but has the median tubercle much farther forward. *Peronopsis callavei* (Raw) Lake has a similarly shaped posterior portion on the axial lobe of the pygidium, but is otherwise quite unlike *Peronopsis planulata.*

Horizon and locality.—A single pygidium was found in the main zone of the Missisquoi at Highgate Falls, Vermont; it is No. 1729 in the Museum of Comparative Zoology.

Subfamily *Phalacrominae* Corda.

Phalacroma parilis (Hall).

Pl. 12, fig. 8.

Agnostus parilis HALL, 16th Rept. N. Y. State Cab. Nat. Hist., Vol. 16, p. 178, Pl. 10, figs. 24, 25, 1863.

A single specimen from Vermont corresponds very well with the shield which Hall described as the head of this species, lacking only the semi-lunate depression at the proximal end. That the width exceeds the length in our form is probably due to distortion, as a slight twisting of the shell is obvious.

Description.—The shield is smoothly and evenly convex, with a flattened margin which is widest at the distal end, and tapers proximally until the sides become evenly convex. At the articulatory or proximal end there is a projecting half-rib on either side, delimited by a very narrow furrow which is confined to the pleural lobes, and does not cross the median portion. This latter, if viewed in profile, is seen to be indented, and there is a small, median, forward-pointed tubercle at the crest of this concave area. This is not of course to be confounded with the upward directed median tubercle near the middle of the shield. The conformation of the articulatory end indicates that this shield is a pygidium and not a cephalon as supposed by Hall. The concavity at the proximal end is the place of articulation with the hindermost thoracic segment, and since the edge of the shield went beneath the segment, it is evidently a pygidium and not a cephalon.

Measurements.—The pygidium is 3 mm. long and 3.25 mm. wide.

Horizon and locality.—The figured specimen was found in zone 2 of the Missisquoi at Highgate Falls, Vermont, and is in the Yale University Museum. The originals were said by Hall to have been found in a "yellowish or drab-colored sandstone, on the shores of Lake Pepin." Walcott has reported the species from the Franconia formation.

Phalacroma cyclostigma Raymond.

Pl. 12, fig. 4.

Phalacroma cyclostigma RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 397, Pl. 12, fig. 4.

Description.—Known from the cephalon only. Cephalon moderately and evenly convex, with a relatively wide, flat border; surface smooth, without furrows, but with the axial lobe suggested by three pairs of low, circular, flat-topped elevations, which, as the specimens are casts, indicate scars on the inner surface of the shield. Two of these elevations are situated close to the posterior margin, and the others are very close to and in front of them. The median tubercle is conspicuous, far back, conical, and surrounded by four of the scars. In front of the first pair of plainly visible scars are indistinct traces of another pair.

Measurements.—The holotype is 4.0 mm. long, 4.5 mm. wide near the front, and the median tubercle is 3.5 mm. from the anterior margin.

Comparisons.—This species differs from *Phalacroma parilis* (Hall) in having a somewhat less convex surface, a wider flattened border, and in the presence of three pairs of elevations on the cast. The latter feature distinguishes it from all other species of the genus.

Horizon and locality.—A rare species in the main zone of the Missisquoi at Highgate Falls, Vermont. Type in the Yale Univesity Museum.

Family SHUMARDIIDAE Lake.

Genus **Idiomesus** Raymond.

Small blind trilobites with short dorsal furrows. Glabella broad, faintly or not at all delimited in front; not lobed.

Genotpye, *Idiomesus tantillus* Raymond.

Idiomesus tantillus Raymond.

Pl. 12, fig. 10.

Idiomesus tantillus RAYMOND, Proc. Boston. Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 397, Pl. 12, fig. 10.

Description.—Cranidium small, semicircular in outline, gently convex, without concave border. Glabella long, oval in outline, without furrows. The dorsal furrows diverge gradually from the posterior margin to about the middle of the head, then converge and become very faint. On some specimens they disappear entirely; on the others they can be traced until they unite in front of the glabella close to the anterior margin. Fixed cheeks evenly convex, deflected at sides and front, ending in blunt genal angles. Occipital furrow narrow and deep, the marginal segment very narrow. There is a minute median pustule on the neck-ring. Surface smooth.

Measurements.—A cranidium is 2 mm. long, 4 mm. wide; the glabella is 1.25 mm. wide at the back and 1.50 mm. in the middle.

Comparisons.—The only species with which one can compare this form are members of the genus Shumardia. In that genus also the cephalon is small and without depressed border, but the glabella spreads out at the front.

Horizon and locality.—This is a common fossil in zones 2 and 3 of the Missisquoi at Highgate Falls, Vermont. Type in the Yale University Museum.

Family ENDYMIONIIDAE Raymond.

Genus **Pseudosalteria** Raymond.

Endymioniidae with depressed-convex, broad cephalon, elliptical glabella with no glabellar furrows or only faint traces of them.

Genotype, *Pseudosalteria laevis* Raymond.

This genus is proposed to include trilobites which resemble Endymionia but lack the lobation of the glabella, and also suggest Salteria, but have less strongly marked glabellar furrows, a shorter glabella, and no raised marginal rim. Free cheeks appear to have been exceedingly narrow, which of course differentiates the genera.

Pseudosalteria laevis Raymond.

Pl. 12, fig. 11.

Pseudosalteria laevis RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 398, Pl. 12, fig. 11.

Description.—Cephalon semicircular, depressed-convex, without concave border or raised rim on the margin. Glabella large, elliptical, raised only a little above the cheeks, outlined by a shallow circum-glabellar furrow. Two pairs of glabellar furrows and the neck-furrow are represented by three pairs of slight depressions on the sides of the glabella. Cheeks evenly convex, sloping down to the margin. Directly in front of the glabella there appears to be a convex border for a short distance. Except for the pair of depressions already mentioned there is no occipital furrow and the posterior margin of the head is somewhat beveled.

Measurements.—Length of cephalon 2.75 mm., width 5 mm.; length of glabella 2 mm., width in middle 1.75 mm.

Horizon and locality.—A single cephalon was obtained from zone 1 of the Missisquoi at Highgate Falls, Vermont, and is in the Yale University Museum.

Pseudosalteria welleri Raymond.

Microdiscus ? sp. und., WELLER, Pal. New Jersey, Vol. 3, p. 114, Pl. 3, fig. 11, 1902.
Pseudosalteria welleri RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 399.

Weller figured a single small imperfect cephalon which has the same outline as *Pseudosalteria laevis,* a similar glabella and cheeks. It differs chiefly in showing no traces of glabellar furrows and in having a narrow median longitudinal furrow in front of the glabella. The length is 5 mm.

Horizon and locality.—From the Upper Cambrian at Newton, New Jersey.

Order OPISTHOPARIA Beecher.

Family CONOCORYPHIDAE Angelin.

Genus **Phoreotropis** Raymond.

This generic name is proposed for simple trilobites with very narrow, marginal free cheeks, small eyes, and with no concave border on the cephalon. The glabella is narrow, parallel-sided, or expanding slightly forward. Glabellar furrows nearly or quite absent.

Genotype, *Phoreotropis puteatus* Raymond.

Phoreotropis puteatus Raymond.

Pl. 12, fig. 12.

Phoreotropis puteatus RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 399, Pl. 12, fig. 12.

Description.—Cranidium small, nearly semicircular, without concave margin. Glabella long, narrow, parallel-sided, the dorsal furrows ending in pits beside the anterior end, which merges into the convex front of the cranidium. Glabellar furrows faint. The first two pairs are represented by small pits in the dorsal furrows; the last pair connect across the glabella as a very faint groove. Fixed cheeks wide, convex, about as high as the glabella. Palpebral lobes small, situated about half-way to the front. The facial sutures extend almost straight forward from the eyes to the anterior margin, and back of the eyes curve outward and then backward to the posterior edge. The occipital furrow is narrow and faint, the segment narrow. Surface smooth.

Measurements.—Length 2 mm.; width at the palpebral lobes 2.25 mm., at the posterior margin 2.50 mm.

Comparisons.—This species differs from the *Idiomesus tantillus* in having a longer glabella, traces of glabellar furrows, and definite palpebral lobes. It is more like *Conocoryphe olenoides* Salter but has a shorter cranidium and there is no limitation of the front of the glabella.

It is of course quite possible that this trilobite is not mature, but if so, the adult form is still unknown.

Horizon and locality.—A single imperfect cranidium was 2 of the Missisquoi at Highgate Falls, Vermont, and is in the Yale University Museum.

Phoreotropis transversus Raymond.

Pl. 12, fig. 16.

Phoreotropis transversus RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 400, Pl. 12, fig. 16.

Description.—Cranidium less than three-fourths as long as wide, moderately convex, rather flat on the upper side. Glabella depressed convex, not greatly elevated above the cheeks; without furrows. The dorsal furrows are straight, converge slightly forward but do not meet in front of the glabella, the anterior end of which merges into the general surface. Palpebral lobes small, very far from the dorsal furrows, situated about midway in the length. Occipital furrow narrow, and faint on axial lobe, where it limits a narrow neck-ring, absent from the cheeks.

Measurements.—Length of cranidium (holotype) 2.75 mm.; width at palpebral lobes 3.50 mm., at posterior margin 4 mm.; width of glabella at back 1.75 mm.

Comparisons.—This species is distinguished from *Phoreotropis puteatus* chiefly by its relatively greater width.

Horizon and locality.—A single cranidium was found in zone obtained from zone 3 of the Missisquoi at Highgate Falls, Vermont, and is in the Yale University Museum.

Phoreotropis olenoides (Salter).

Conocoryphe olenoides SALTER, Mem. Geol. Surv. Great Britain, Vol. 3, p. 308, Pl. 8, fig. 6, 1866.

This species, known from a cranidium, has been imperfectly described but appears to be referable to the present genus. The glabella is narrow, but expands slightly forward, and the free cheeks are somewhat wider than in the American species.

Horizon and locality.—From the Upper Tremadoc at Garth, Portmadoc, Wales.

Family OLENIDAE Burmeister.

Genus **Zacompsus** Raymond.

This generic name is suggested for trilobites apparently allied to Ctenopyge, but differing from that genus in the absence of glabellar furrows, the anterior enlargement of the glabella, and in having the eye-lines directed forward instead of backward. Orometopus has a somewhat similar cranidium, with a furrowless glabella, but shows a pair of anterior pits, posterior extra-glabellar mounds, and a nuchal spine, all of which produce an aspect which is on the whole, quite different from that of the specimens now to be described.

Genotype, *Zacompsus clarki* Raymond.

Zacompsus clarki Raymond.

Pl. 12, fig. 13.

Zacompsus clarki RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 401, Pl. 12, fig. 13.

Description.—Cranidium small, trapezoidal, the width about twice the length. Glabella narrow, enlarging forward and extending nearly to the front; anterior end semicircular in outline. No glabellar furrows present. Fixed cheeks wide, depressed toward the glabella and posterior margin, but rising toward the eyes, which are apparently far from the glabella, although lost from both the specimens so far found. The brim is narrow, mostly concave, without rim, but rises into two little mounds situated near the margin and in line with the dorsal furrows. A pair of high ocular ridges run forward and outward from the sides of the glabella, leaving it at about the mid-length. Occipital furrow narrow, deeper on the cheeks than on the axial lobe. Occipital segment very narrow.

Measurements.—A cranidium, the holotype, is 2 mm. long and 5 mm. wide. The glabella is 1.80 mm. long and 1 mm. wide at the widest point.

Horizon and locality.—Two cranidia were obtained from zone 2 of Missisquoi at Highgate Falls, Vermont. Named for Dr. T. H. Clark, who is making contributions to the study of the "Taconic" question. Holotype in Yale University Museum.

Genus **Westergardia** Raymond.

This name was proposed for a group of species now referred to Boeckia. They possess depressed-convex cephala, with a large smooth semi-elliptical glabella which reaches nearly to the anterior margin, and wide free cheeks with a narrow marginal rim. The position of the eyes is variable, either central, or far back. Only the cephalon is surely known.

Genotype, *Boeckia scanica* Westergard (1909, p. 50, Pl. 1, figs. 9-13; 1922, Pl. 16, figs. 40-43).

Westergard himself states that it is very doubtful if the two species, *Boeckia scanica* and *Boeckia ? illaenopsis* which he described from the Acerocare zone in southern Sweden really are congeneric with Wiman's genotype, *Boeckia mobergi* (Wiman, 1902, p. 81, Pl. 5, figs. 9-13). The latter species has very much the aspect of a Ctenopyge in all parts, whereas the species *Boeckia scanica* and *Boeckia ? illaenopsis* resemble Peltura, and are even more like Cyclognathus, which appears to be the "smoothed out" member of the Peltura line (Westergard, 1922, p. 203, Pl. 16). Westergardia appears to differ from Cyclognathus chiefly in having the eyes farther back and the glabella less elevated.

Westergard figures one nearly complete specimen as *Boeckia scanica,* but I have not included in the generic description any characteristics derived from it, because in the figure the eyes appear so far forward as to suggest *Cyclognathus granulatus* (Moberg and Moller). It has nine thoracic segments and a short, nearly semicircular pygidium. Cyclognathus is said to have from nine to twelve thoracic segments.

Genus **Phylacterus** Raymond.

Olenidae apparently allied to Westergardia, but with an angulated raised rim on the front of the cranidium. Facial sutures as in Cyclognathus.

Genotype, *Phylacterus saylesi* Raymond.

Phylacterus saylesi Raymond.

Pl. 12, figs. 14, 15, 18.

Phylacterus saylesi RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 403, Pl. 12, figs. 14, 15, 18.

Description.—Cranidium short and broad, indicating a cephalon nearly semicircular in outline. Glabella ovate, about two-thirds the total length, moderately convex, tapering but little toward the front, and bearing two pairs of short, obliquely placed furrows. The cheeks rise in a gentle, convex curve from the dorsal furrows, forming a low smooth ridge in front of the glabella, and broad cheeks at the sides. The eyes are apparently small, although the palpebral lobes are broken from all specimens in the collection, and situated at about the midway of the cranidium, at some distance from the glabella, to frontal lobe of which they are connected by ocular ridges. The fixed cheeks back of the eyes extend far outward. At the middle of the front of the cranidium there is for a short distance a raised border, separated by a narrow furrow from the roll behind it. This border is crossed by the facial sutures, giving a triangular appearance to the front. An obscure ridge passes along the median line from the border across the furrow behind it, and through a slight depression in the roll to the front of the glabella. The surface of the whole is granulose.

A pygidium which may well belong to this species is small, with a wide, prominent axial lobe, and narrow, depressed lateral ones. The axial lobe has one prominent ring and two faint ones. The pleural lobes are so far depressed as to be almost concave and each has two narrow ribs close to the anterior margin, separated by a deep furrow. The posterior rib is often obscure. There is a very narrow slightly convex rim.

Measurements.—The cranidium selected as the holotype is 7.0 mm. long, about 7.0 mm. wide at the palpebral lobes, and 12.5 mm. at the nuchal segment. The glabella is 4.5 mm. long and 4.0 mm. wide at the base.

The pygidium (paratype) is 2 mm. long, 2.75 mm. wide, and the axial lobe is 1.75 mm. long and 1.25 mm. wide at the front.

Comparisons.—This species has a longer and narrower cephalon than *Phylacterus fraternus,* glabellar furrows, although obscure, are present, and the longitudinal ridge in front of the glabella is more obscure. The very wide fixed cheek, which indicates that the posterior end of the free cheek must have had the peculiar form of that of Cyclognathus, allies this form with Westergardia, but the presence of the angulated rim and wide brim precludes its inclusion in that genus.

Horizon and locality.—A number of specimens have been found in the main fossiliferous zone of the Missisquoi at Highgate Falls, Vermont. Named for Mr. Robert W. Sayles.

The types are in the Yale University Museum.

Phylacterus fraternus Raymond.

Pl. 12, fig. 19.

Phylacterus fraternus RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, p. 404, Pl. 12, fig. 19.

Description.—Cranidium small, about half as long as wide, gently convex, sloping downward and outward at the sides. Glabella nearly one-third the total width, semi-elliptical, depressed convex. Circum-glabellar furrow wide and shallow, extending in front as a shallow median depression crossing the brim. Eyes small, midway in the cephalon, distant from the glabella about one-half its width. Eye-lines are present, but very faint. Back of the eyes the facial sutures continue backward but a very short distance, then turn abruptly outward to the genal angles, making very wide fixed cheeks as in Peltura, Cyclognathus and their allies. The occipital furrow is shallow on the axial lobe, narrow but distinct on the cheeks.

Measurements.—Length of the cranidium (holotype) 3.5 mm., width at palpebral lobes 4.5 mm., width at posterior margin 6.5 mm.; length of glabella 2.25 mm., width at back 2 mm.

Comparisons.—This species is very like *Westgardia scanica,* but has a proportionally narrower glabella and a wider brim. *Westergardia illaenopsis* has the eyes much farther back. The cranidium is shorter than that of *Phylacterus saylesi.*

Horizon and locality.—There is a single specimen from zone 3 of the Missisquoi at Highgate Falls, Vermont.

Family SOLENOPLEURIDAE Angelin.

Genus Onchonotus Raymond.

Levisia WALCOTT, (partim), Smithson. Misc. Coll., Vol. 7, No. 4, p. 86, 1911.

Levisia was not, as would be supposed, based upon a Canadian trilobite, but upon *Agraulos agenor* Walcott, a member of the Chinese Middle Cambrian fauna. The type is a minute cranidium with a large, strongly convex glabella, a broad, blunt occipital spine, and rather wide, elevated fixed cheeks. Walcott named and figured two species from Lévis as members of this genus. These forms, known as *Levisia richardsoni* and *Levisia nasuta,* differ from *Levisia agenor* in lacking an occipital spine and in having the fixed cheeks depressed, drooping away from the glabella, instead of rising into high ridges outside the dorsal furrows. The brim of the type is convex, separated from the glabella by a very narrow concave region, whereas in the species from Lévis, the brim is concave, with a narrow rim.

Levisia richardsoni and *Levisia nasuta* are forms which earlier students of the fossils in the boulders at Lévis have identified as *Menocephalus globosus.* They agree with that species in the drooping cheeks, the highly convex, unfurrowed glabella, and the small eyes. All three have a peculiar tongue-like anterior prolongation of the brim. The chief difference is that *Menocephalus globosus* has a pustulose surface, whereas that of the species referred by Walcott to Levisia is smooth or finely reticulate. The genus Menocephalus will have to be discarded. Owen (1852, p. 577, Pl. 1, fig. 11) proposed the name for a glabella and part of a cheek, inadequately figured and described, and, according to Walcott (1913, p. 172) the type is lost. Dr. Walcott, after studying specimens from the original locality could not identify the species, and nothing can be gained by trying to preserve the name. The three species, *Levisia richardsoni, Levisia nasuta,* and *Menocephalus globosus,* appear to be congeneric, and for them the name Onchonotus is proposed, with the following description.

Description.—Opisthoparia with bulbous, nearly or quite unfurrowed glabella, wide drooping cheeks and nasute brim, small eyes at or just in front of the middle of the head.

Genotype, *Menocephalus globosus* Billings.

This genus is closely allied to Clelandia Cossman (Harrisia, Cleland, 1900, p. 127, Pl. 16, figs. 1-3). Both have drooping cheeks and a nasute projection in front of the glabella, small eyes, and unfurrowed glabella. The free cheeks meet in front of the glabella in Clelandia, however, and are widely separated in Onchonotus. The eyes of the former are far forward, opposite the anterior end of the glabella.

Onchonotus richardsoni (Walcott).

Levisia richardsoni WALCOTT, Smithson. Misc. Coll., Vol. 57, No. 4, Pl. 17, figs. 4, 4a, 1911; Cambrian Fauna of China, p. 178, 1913.

Walcott named and figured *Levisia richardsoni* and *Levisia nasuta* from specimens obtained from the boulders at Lévis. In the absence of any description of either species one is obliged to depend upon the figures, from which I infer that *Levisia richardsoni* differs from *Levisia nasuta* in having a wider occipital segment and in having the edge of the brim turned up instead of down. There are in the Museum of Comparative Zoology several cranidia which may be assigned to Onchonotus, and two species appear to be represented, neither of them *Onchonotus globosus.* The one with the wider occipital ring I take to be *Onchonotus richardsoni.* The other can definitely be identified as *Onchonotus nasutus.*

The cranidium from Lévis, which I believe to represent *Onchonotus richardsoni,* has a large, highly convex glabella which is longer than wide, rises abruptly from the occipital furrow, and tapers very slightly toward the front. The brim slopes downward away from the glabella, is nearly flat, with a slightly nasute up-turned anterior border. The fixed cheeks back of the eyes are small, bowed downward, and the narrow, deep, occipital furrow marks off a narrow raised marginal border. The neck-furrow on the axial lobe is deeper and wider than on the cheeks, and the neck-ring is extended a little backward and upward. The palpebral lobes are of medium size and their centers are only slightly in front of the middle of the head. The shell is entirely removed so the nature of the surface cannot be ascertained.

Measurements.—Length of cranidium 11 mm., width at palpebral lobes 10 mm., at posterior margin about 17 mm. Length of glabella 7 mm., width at back 6 mm.

Horizon and locality.—This species has so far been found only in the boulders of the conglomerate at Lévis, Province of Quebec.

Onchonotus nasutus (Walcott).

Levisia nasuta WALCOTT, Smithson. Misc. Coll., Vol. 57, No. 4, p. 87, text-figs. 7, 7a, Pl. 17, fig. 5, 1911; Research in China, Vol. 3, p. 178, 1913.

Description.—Cephalon very highly convex, surmounted by a vaulted glabella which is longer than wide, evenly convex, and without furrows. The brim is concave, turns downward, and then up at its tongue-like median projection. Dorsal furrows narrow, not deep, cheeks convex, drooping. Eyes small, slightly in front of the middle, and very close to the glabella. Occipital furrow narrow but deep, the segment, including the neck-ring, narrow. Free cheeks large, convex, with a narrow raised border, and a short genal spine.

Measurements.—This species appears to differ from *Onchonotus richardsoni* only in having a narrower neck-ring, though possibly the eyes are a little smaller, closer to the glabella, and farther forward.

Horizon and locality.—Specimens which appear to belong to this species are fairly common at Highgate Falls, Vermont, in zones 2 and 3 of the Missisquoi. All are smaller than any yet seen from Lévis and at sight appear to have a higher and narrower glabella. This is not, however, borne out by measurements. The original locality was at Lévis, Province of Quebec, where the species seems to be fairly common in some of the boulders of the conglomerates.

Hystricurus mammatus Raymond.

Pl. 12, fig. 17.

Hystricurus mammatus RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 407, Pl. 12, fig. 17.

Description.—Known only from the pygidium, which differs from that of *Hystricurus cordai* (Billings) in being longer, but with a relatively shorter axial lobe. The specimen is laterally compressed, but the pleural lobes appear to have been naturally narrow, and, besides the anterior half-rib, there are only two pairs of ridges on them. Each rib bears two pairs of elongate pustules on its inner half, and a pair of pustules on either side indicates the position of a third pair of ribs. The axial lobe is convex, narrow, expands forward, and shows six rings, each with a row of elongated pustules. The ribs are short so that there is a wide smooth border, which slopes rather steeply and is not definitely concave.

Measurements.—Length of pygidium 12 mm., width 11 mm., length of axial lobe 9 mm., width at front 4 mm. As the specimen is laterally compressed, these widths are too small.

Horizon and locality.—From the Georgia formation, 4.5 miles north of Highgate, Vermont. Type in the Yale University Museum.

Family ASAPHISCIDAE Raymond.

There are a number of trilobites with relatively large pygidia and few thoracic segments, which have somewhat the appearance of members of the Asaphidae, and have sometimes been referred to that family, or to the Bathyuridae.

The Asaphiscidae differ from the Asaphidae in having a variable number of thoracic segments (7-11), in having the glabella always tapering forward, whereas it generally expands forward in the Asaphidae, and in retaining many primitive characteristics which are lost by most members of the Asaphidae. For example, the facial suture is always marginal at the front, eye-lines are generally present, the axial lobe is always narrow, and is always well defined, even in specialized forms (Blountia). The Bathyuridae differ from the Asaphiscidae in having a longer, parallel-sided glabella, a fixed number of thoracic segments, and usually, larger eyes.

Just what genera really belong to the family cannot be fully determined. Asaphiscus Meek, Blountia Walcott, and Maryvillia Walcott appear to be rather closely allied, and Blainia Walcott probably belongs to the family, although it has a more primitive cephalon than Asaphiscus. Lloydia Vogdes can apparently be placed in the Asaphiscidae, although the glabella is much longer than in the genera previously mentioned.

Asaphiscus inornatus Raymond.

Pl. 12, fig. 23.

Asaphiscus inornatus Raymond, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 409, Pl. 12, fig. 23.

Description.—Cranidium more than half as long as wide, depressed-convex, smooth. Glabella large, depressed-convex, semi-elliptical, rounded in front, without glabella furrows. Brim flat, sloping gently away from the glabella, then suddenly turned upward to form a convex, lip-like border. Palpebral lobes of medium size, close to the dorsal furrows. The facial sutures are practically identical in course with those of *Asaphiscus wheeleri.* Occipital furrow broad and shallow, the segment narrow and flat.

Measurements.—The cranidium (holotype) is 8 mm. long, 6.25 mm. wide at the palpebral lobes and 11 mm. at the posterior margin.

Comparisons.—This cranidium is, except for the absence of eye-lines, an almost exact miniature of that of *Asaphiscus wheeleri.* It undoubtedly does not belong to that species, however, and it should be pointed out that, with only isolated cranidia at hand it is not possible to make even the generic identification with confidence.

Horizon and locality.—Two cranidia were found in zone 1 of the Missisquoi at Highgate Falls, Vermont, and are in the Yale University Museum.

Blountia imitator Raymond.

Pl. 12, fig. 22.

Blountia imitator Raymond, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 409, Pl. 12, fig. 22.

Description.—Cranidium small, sub-rectangular, moderately convex. Glabella semi-elliptical in outline, short, highly convex, without furrows. Brim gently convex, nearly flat, inclined downward, and bordered by an upturned edge. Palpebral lobes large, close to the dorsal furrows. The course of the facial suture from the anterior end of the eye is straight, and makes an angle of about 30° with a line parallel to the axis. Occipital furrow shallow, the segment flat.

Measurements.—Length of cranidium of holotype 5.75 mm., width at palpebral lobes 5.75 mm.

Comparisons.—This species somewhat closely resembles *Asaphiscus inornatus,* but is more convex, proportionally shorter, and has a somewhat narrower brim. It has much the same form as the type of the genus, *Blountia mimula* Walcott (1916, p. 399, Pl. 61, fig. 4-4c) but has a shorter and more elevated glabella.

Horizon and locality.—A single cranidium was found in zone 2 of the Missisquoi at Highgate Falls, Vermont, and is in the Yale University Museum. The other species of the genus are all in the Upper Cambrian of eastern Tennessee.

Maryvillia triangularis Raymond.

Pl. 12, fig. 21.

Maryvillia triangularis Raymond, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 410, Pl. 12, fig. 21.

Description.—Two imperfect pygidia appear referable to this genus. They are almost triangular, evenly convex, without depressed border. The axial lobe is narrow, with very faintly outlined rings, and extends nearly to the posterior end. The pleural lobe shows the usual anterior half-rib, and faint traces of five or six more.

Measurements.—A pygidium is 8.25 mm. long, was approximately 12 mm. wide at the front, and the axial lobe is 7 mm. long.

Comparisons.—It may be that this species should have been referred to Blountia rather than Maryvillia, but although the axial lobe is nearly destroyed, it shows sufficient remnants of rings to indicate Maryvillia. Moreover, this pygidium is 8.25 mm. long, and Dr. Walcott states that no known species of Blountia appears to have been much over 10 mm. in length when entire, whereas Maryvillia is a larger trilobite. An important feature in the present speceis is the absence of a concave border which is characteristic also of *Maryvillia ariston* Walcott (1916, p. 401, Pl. 64, fig. 5a).

Horizon and locality.—A single specimen was found in zone 3 of the Missisquoi at Highgate Falls, Vermont, and another in the Highgate at Highgate Center. The former is the holotype, and is in the Yale University Museum.

Lloydia seelyi (Walcott).

Pagodia seelyi Walcott, Smithson. Misc. Coll., Vol. 57, No. 9, p. 269. Pl. 44, figs. 12, 12a, 13, 13a, 14, 14a, 1912.

The species which Dr. Walcott figured under this name has a long pygidium which is quite typically Lloydia-like, with its narrow, smooth border, long axial and smooth pleural lobes. The pygidium of Pagodia on the other hand, is short, rounded behind and has conspicuous ribs.

The cranidium of *Pagodia seelyi* is, it is true, very like that of *Pagodia lotos,* but it is also like that of *Lloydia oblonga.* If cranidium and pygidium belong together, as they probably do, it seems more natural to refer them to an American than to a Chinese genus.

Description.—The pygidium is long, narrow, somewhat triangular, with a narrow elevated border which is conspicuously continuous with the anterior half-segment. The axial lobe is narrow, with three rings at the anterior end, the posterior portion smooth. Pleural lobes evenly convex, smooth, separated from the border by a narrow but distinct furrow.

Measurements.—Length of pygidium 9 mm.; width at anterior end 9.5 mm.; width of axial lobe at anterior end 2.25 mm.

Comparisons.—These pygidia have two less rings on the axial lobe than the specimen figured by Walcott, but otherwise the agreement is perfect. They differ from *Lloydia saffordi* (Billings) in being smaller, proportionately longer, and in having a narrower axial lobe.

Horizon and locality.—One flattened pygidium was obtained from zone 3 of the Missisquoi at Highgate Falls, Vermont, and another not crushed but with the axial lobe somewhat damaged, from the lower part of the Highgate limestone, north of Highgate Center, Vermont. The original specimens described by Walcott were found in the Potsdam sandstone near Port Henry, New York.

Lloydia saffordi (Billings).

Bathyurus saffordi BILLINGS, Can. Nat. Geol., 1860, Vol. 5, p. 320, fig. 24; ibid., Vol. 6, 1861, p. 313, figs. 1, 2; Geol. Canada, 1863, p. 239, figs. 274a, b.—CHAPMAN, Canadian Journal, n. s., 1863, Vol. 8, p. 29, fig. 142a; p. 192, fig. 162; Expos. Miss. Geol. Canada, 1864, p. 137, fig. 142a; p. 164, fig. 162.—BILLINGS, Pal. Foss. Canada, 1865, Vol. 1, p. 259, figs. 241a, b; p. 411, fig. 393.

Lloydia saffordi RAYMOND, Bull. Victoria Mem. Mus., 1913, Vol. 1, p. 67, Pl. 7, fig. 16.

This species is very common in the Beekmantown at Philipsburg, Province of Quebec, and in the conglomerates at Point Lévis. A single imperfect pygidium was obtained from the Georgia formation 4.5 miles north of Highgate Center, Vermont. It is somewhat more than usually convex, and the border is a little wider than usual, but it comes within the limits of the variations shown by specimens from Philipsburg.

Pygidia from the Williston formation on the Hinesburg Road southeast from Burlington, Vermont, have the typical shape of *Lloydia saffordi,* but the annulation of the axial lobe is unusually faint. This does not, however, seem sufficiently important to justify a specific separation.

In the lower part of the Highgate limestone about 1.5 miles north of Highgate Center representatives of this genus appear to be fairly common, and show considerable variations. Six entire pygidia were obtained: five which may be assigned to the typical variety, and one which agrees with a broad-margined type found also at Philipsburg.

Family PLETHOPELTIDAE nov.

After the original edition of this article went to press, Dr. Walcott published a paper on "Cambrian and Lower Ozarkian Trilobites" (Smithson. Miscl. Colls., 1924, Vol. 75, No. 2, pp. 53-60) in which he has described three new genera closely allied to Plethopeltis. Kingstonia Walcott differs from Plethopeltis in the entire absence of the nuchal furrow and the presence of a vertical anterior border. The glabella is delimited by a very narrow and shallow furrow. The type is *Kingstonia apion* Walcott, from the Upper Cambrian of Maryville, Tenn.

Ucebia Walcott has a highly arched median portion of the cephalon, the dorsal furrows indicated only at the posterior margin, and no nuchal furrow. The glabella is differentiated only by being slightly higher than the cheeks. There is no anterior border. The type is *Uceba ara* Walcott, from the Upper Cambrian of the Rocky Mountains.

Bynumia Walcott differs from the allied genera in having a triangular frontal extension which gives it a strikingly different appearance from Plethopeltis, although the presence of a circumglabellar and nuchal furrows shows that it is closely allied. The type is *Bynumia eumus,* from the Upper Cambrian of British Columbia.

These three genera, with Leiocoryphe Clark (Bull. Am. Palaeontology, 1924, Vol. 10, No. 41, p. 21), Plethopeltis, and Stenopilus Raymond, form so large a group of smooth trilobites that it seems best to remove them from the family Ellipsocephalidae to a new one which may be described as:

Derived Opisthoparia, presumably descended from the Ellipsocephalidae, with small, subhemispheric cephalon, small eyes on steeply sloping cheeks, usually without glabellar furrows, and frequently without dorsal or lateral furrows. Pygidium small, without ribs or concave border. Axial lobe well defined.

Genus **Plethopeltis** Raymond.

Plethopeltis RAYMOND, Victoria Memorial Mus., Bull. 1, p. 64, 1913. —FIELD, Ottawa Naturalist, Vol. 29, p. 37, 1915.

This genus was proposed to include trilobites which are related to Agraulos, but whose cephala have become nearly smooth, through the total loss of the glabellar furrows. The circum-glabellar furrow is also narrow and shallow. In proposing the genus, I had in mind such a trilobite as *Bathyurus armatus* Billings, but unfortunately selected as the genotype *Agraulos saratogensis* Walcott. At the time my paper was written, the latter species was known only from Walcott's diagnosis and figure of 1890, but in his more detailed description of the Saratogan fauna in 1912, *Agraulos saratogensis* was assigned quite different characteristics. As Field pointed out, the specimens figured in Walcott's later paper represent two distinct forms, one of them with very faint glabellar furrows, the other with two pairs of deeply incised ones. Neither, unfortunately, is the holotype, and the text makes no reference to the amount of variability within the species. It, therefore, becomes necessary to restudy the typical species before the value of the genus can be properly appraised.

Plethopeltis saratogensis (Walcott).

Bathyurus armatus WALCOTT (*non* Billings), 32d Ann. Rept. N. Y. State Museum, p. 131, 1879.
Ptychoparia (Agraulos) saratogensis WALCOTT, Bull. U. S. Geol. Surv., No. 30, p. 31, 1886 (*nomen nudum*).
Ptychoparia saratogensis DWIGHT, Trans. Vassar Bros. Inst., Vol. 4, pp. 207, 208, 1887 (*nomen nudum*).
Ptychoparia (Agraulos) saratogensis LESLEY, Geol. Surv. Penna., Rept. 4 P, Dict. of Fossils, Vol. 2, p. 834, fig. 1-4, 1888.
Agraulos saratogensis WALCOTT, Proc. U. S. Nat. Mus., Vol. 13, Pl. 21, fig. 14, 1890; Smithson. Misc. Coll., Vol. 57, p. 269, Pl. 43, fig. 11-15, 1912. Not *Agraulos saratogensis* WELLER, Geol. Surv. New Jersey, Vol. 3, pp. 118, 119, Pl. 1, fig. 7-9, 1903.

This species, as at present defined, is the most abundant of all the trilobites in the Hoyt limestone at the typical locality four miles west of Saratoga. As noted above, Walcott has figured three forms under this name: The original one with glabellar furrows so faint as to be hardly visible, and not shown on the figure (1890, fig. 14); the second (1912, figs. 11, 11a) has faint glabellar and deep dorsal furrows; and the third (1912, figs. 14, 14a) has both the dorsal and the glabellar furrows deeply impressed.

A collection of 37 cranidia from the typical locality contains examples of the first two of these forms, but not the last. More abundant than either is one which has no glabellar and only slightly impressed dorsal furrows, 22 of the specimens belonging to this form. Since the specimen originally described by Walcott had very faint glabellar furrows, that form may be taken as typical of the species. It was at first thought that the specimens with glabellar furrows were immature and the others adult, but since there are large and small individuals of both sorts, it is evident that this is not the explanation. Neither is the difference due to state of preservation for there are specimens of both kinds which retain the test.

Two forms must, then, be recognized, either as representing one variable species, or two distinct but closely related ones. That the latter is the more probable is indicated by the fact that there are two kinds of pygidia associated with the cephala, one much smoother than the other. It is very possible that the smoother cephala and pygidia belong together, and they are accordingly described as a new species. With this form eliminated, the genus Plethopeltis has as its type a trilobite with an almost smooth glabella, but which retains traces of glabellar furrows. The dorsal furrows are narrow but distinct and unite in front. The fixed cheeks form convex lateral and frontal slopes. The new species which is associated with *Plethopeltis saratogensis* is obviously so closely related that the generic definition must be broadened to include species without glabellar furrows, and Plethopeltis may be employed as a designation for those descendents of Agraulos which have a shorter and more convex cephalon, but which still retain a circum-glabellar furrow, or traces of it.

Plethopeltis walcotti Raymond.

Pl. 12, figs. 20, 24.

Plethopeltis walcotti RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 414, Pl. 12, figs. 20, 24.

This name was proposed for the smooth Plethopeltis associated with *Plethopeltis saratogensis* and referred to under that heading.

Description.—Cranidium convex, the length equal to the width between the tips of the fixed cheeks. Glabella half-oval, raised above the general surface, outlined by a narrow circum-glabellar furrow which is generally faintly impressed, but somewhat conspicuous on some specimens. Eyes large, with rather small, flat, lunate palpebral lobes which are situated a little in front of the middle of the cephalon, and close to the dorsal furrows. Nuchal furrow shallow, deepest over the median lobe, fading out at the dorsal furrows, then extending across the fixed cheeks as a narrow, deep groove. The whole neck-ring back of the glabella projects backward in a short, broad, blunt point which is turned slightly upward. The portions of the fixed cheeks back of the eyes are triangular and only gently curved; those in front curve abruptly downward from the circum-glabellar furrow. Free cheeks associated wtih the cranidia have the same form as those of *Plethopeltis saratogensis*. The genal angles are produced into short, acutely angular spines which are oval in section. Thorax unknown.

The associated pygidium is a little more than half as long as broad, with a highly elevated axial lobe, and no concave border. The axial lobe extends four-fifths the length and occupies slightly more than one-third the width. There are three well-defined rings besides the anterior half-ring. The pleural lobes are very nearly smooth, with an anterior, ill-defined rib.

Measurements.—The holotype, a cranidium, is 7 mm. long and 5 mm. wide at palpebral lobes; the glabella—nuchal furrow to anterior end—is 4.5 mm. long and 4 mm. wide at the back. The largest cranidium in the collection is 14 mm. long, the smallest 4 mm. A pygidium, paratype, is 5 mm. long and 9 mm. wide; the axial lobe is 4 mm. long and 3.25 mm. wide at the front.

Horizon and locality.—A common fossil in the Hoyt limestone at the Hoyt quarry four miles west of Saratoga, New York.

Holotype No. 1730, paratype No. 1731, Museum of Comparative Zoology.

Plethopeltis welleri Raymond.

Agraulos saratogensis WELLER, Pal. New Jersey, Vol. 3, p. 118, Pl. 1, figs. 7-9, 1903.

Plethopeltis welleri RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 415.

Description.—The cranidium of the specimen described and figured by Weller is practically identical with those on which *Plethopeltis walcotti* is based, but the free cheek has a much shorter genal spine, and the pygidium is much narrower, with a wider axial lobe which is not bounded posteriorly, but merges into the general surface. Although the principal differences from *Plethopeltis walcotti* are found in the pygidium, which may possibly not be correctly associated with the cranidium, it seems best to assign this species a distinct specific name.

Horizon and locality.—This species was found by Weller in the upper part of the Cambrian about one-half mile north of Blairstown, New Jersey.

Plethopeltis hemispherica (Berkey).

Agraulos hemisphericus BERKEY, American Geologist, Vol. 21, p. 289, Pl. 20, figs. 14, 15, 1898.

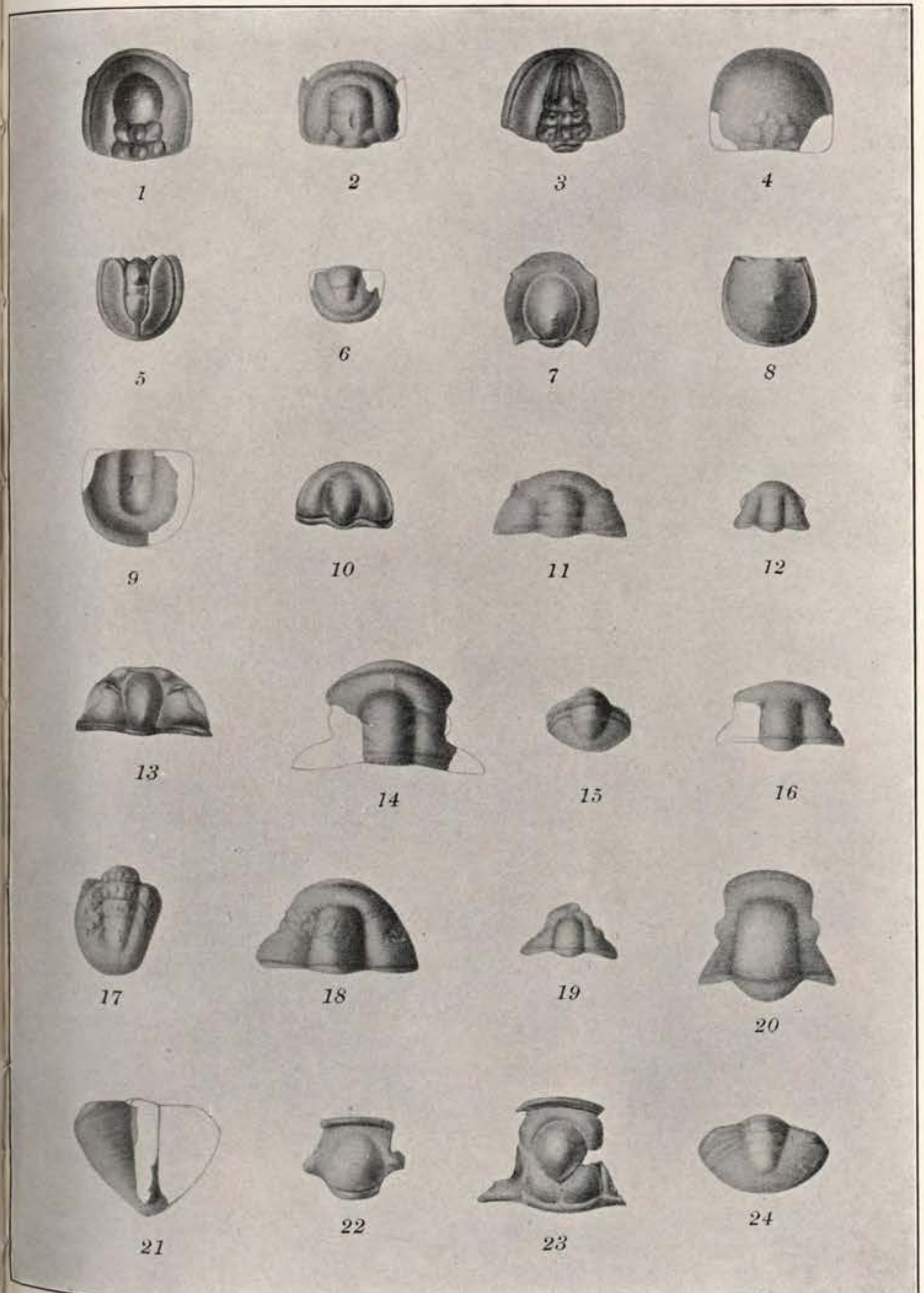
This species is to be referred to Plethopeltis although the eyes are rather farther apart than in the eastern forms. The glabella is less distinctly outlined, less convex, and shorter than that of *Plethopeltis walcotti,* but more sharply set off from the cheeks than in *Plethopeltis armata*. The cranidium is much more nearly square and the fixed cheeks are narrower and more extended laterally behind the eyes than is usual in the genus. It is also noteworthy that the nuchal segment is not drawn out into a blunt spine.

Berkey gives the following measurements: Length of head 15 mm., width 21 mm.; length of glabella 10 mm., exclusive of occipital ring; anterior width 7 mm., posterior width 9 mm.

Horizon and locality.—Berkey's original specimens were from the Upper Cambrian (Franconia) at Taylor's Falls, Minnesota.

Figs. 1, 5. *Agnostus innocens* Clark. × 4.
Figs. 2, 6. *Agnostus insuetus* Raymond. × 6.
Fig. 3. *Agnostus trisectus* Salter. × 4. The ornamentation of the cheeks is not shown.
Fig. 4. *Phalacroma cyclostigma* Raymond. × 4.
Fig. 7. *Pseudagnostus extumidus* Raymond. × 4.
Fig. 8. *Phalacroma parilis* (Hall). × 4.
Fig. 9. *Peronopsis planulata* Raymond. × 4.
Fig. 10. *Idiomesus tantillus* Raymond. × 4.
Fig. 11. *Pseudosalteria laevis* Raymond. × 4.
Fig. 12. *Phoreotropis puteatus* Raymond. × 4.
Fig. 13. *Zacompsus clarki* Raymond. × 4.
Fig. 14. *Phylacterus saylesi* Raymond. × 2.
Fig. 15. The same species. × 4.
Fig. 16. *Phoreotropis transversus* Raymond. × 4.
Fig. 17. *Hystricurus mammatus* Raymond. × 2.
Fig. 18. *Phylacterus saylesi* Raymond. The holotype. × 2.
Fig. 19. *Phylacterus fraternus* Raymond. × 2.
Figs. 20, 24. *Plethopeltis walcotti* Raymond. × 2.
Fig. 21. *Maryvillia triangularis* Raymond. × 2.
Fig. 22. *Blountia imitator* Raymond. × 2.
Fig. 23. *Asaphiscus inornatus* Raymond. × 2.

PLATE XII.



Mr. W. A. Finkelnberg collected at Ironton, Wisconsin, two cranidia which are now in the Museum of Comparative Zoology.

Plethopeltis arenicola Raymond.

Pl. 13, fig. 1.

Plethopeltis arenicola RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 416, Pl. 13, fig. 1.

Three cranidia from the Upper Cambrian of Wisconsin represent a new species of Plethopeltis allied to *Plethopeltis hemisphaerica.*

Description.—Cranidium almost evenly convex, the glabella rising above the general surface only at the posterior end. Dorsal furrows obsolete except as faint depressions at the posterior ends. Nuchal furrow very faintly impressed; nuchal ring narrow, without an axial point. Palpebral lobes not well preserved, but apparently small, narrow, and situated slightly behind the middle. All specimens are casts of the interior preserved in sand, and the furrows may have been more deeply impressed on the shell, although this is not to be expected.

Measurements.—Holotype: Length of cranidium 19 mm., width at palpebral lobes 21 mm.; width of axial lobe at posterior margin 12 mm. Another cranidium is 20 mm. long and about 21 mm. wide at the palpebral lobes.

Horizon and locality.—The specimens were collected by Mr. W. A. Finkelnberg at an undetermined horizon of the Upper Cambrian at Ironton, Wisconsin, and are now in the Museum of Comparative Zoology. The holotype is No. 1732.

Plethopeltis armata (Billings).

Bathyurus armatus BILLINGS, Canadian Nat. and Geol., Vol. 5, p. 319, fig. 23, 1860; Geology of Canada, p. 238, fig. 273, 1863; Pal. Foss. Canada, Vol. 1, p. 411, fig. 392, 1865.

Plethopeltis armata RAYMOND, Bull. Victoria Mem. Mus., p. 65, Pl. 7, fig. 18, 1913.

Two cranidia have been identified as belonging to this species. They are much smaller than the type but have the same outline and the characteristic nuchal spine, which is somewhat longer than in other species of the genus. The dorsal furrows show only along the posterior portion of the glabella.

Measurements.—Length of a cranidium 6 mm.; width at fixed cheeks about 6 mm.; width of glabella at posterior end 3 mm. Billings' type is 18 mm. long.

Horizon and locality.—The type was obtained (probably from a boulder) from Limestone No. 1, a conglomerate, at Point Lévis, Quebec. Professors Schuchert and Dunbar collected two specimens from their zone 3 and another from zone 2 of the Missisquoi formation in the gorge at Highgate Falls, Vermont.

Plethopeltis laevis Raymond.

Pl. 13, fig. 3.

Plethopeltis laevis RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 417, Pl. 13, fig. 3.

Description.—This species may be briefly characterized by stating in what particulars it differs from those to which it is closely allied. It belongs to the group without a nuchal spine, which at once eliminates all except *Plethopeltis angusta, Plethopeltis lata,* and *Plethopeltis arenicola.* It is wider than *Plethopeltis angusta,* has the eyes nearer the glabella, hence wider free cheeks than *Plethopeltis lata,* and has a much more sharply delimited and prominent neck-ring than *Plethopeltis arenicola.* The glabella is faintly outlined by furrows which extend nearly as far as the eyes.

Measurements.—Length of holotype 4.75 mm.; width at palpebral lobes 3.5 mm.; width at fixed cheeks 5.75 mm.

Horizon and locality.—Six cranidia of this species were collected from zone 3 of the Missisquoi at Highgate Falls, Vermont. The holotype is in the Yale University Museum.

Plethopeltis angusta Raymond.

Pl. 13, figs. 4, 8.

Plethopeltis angusta RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 417, Pl. 13, figs. 4, 8.

Description.—Cephalon narrow, highly vaulted, compressed so that the fixed and free cheeks are nearly vertical, and hardly visible from above. Glabella entirely smooth, not outlined in any way. Nuchal furrow obsolete on fixed and free cheeks, faintly visible across the axial lobe. Nuchal segment drawn out into a short blunt spine. The eyes are very small, situated just in front of the middle of the cephalon, and half-way down the lateral slopes. The free cheeks are wide, smooth, and have broadly rounded genal angles which extend but slightly behind the tip of the nuchal spine.

Measurements.—The holotype is 5 mm. long, 3.75 mm. wide at the palpebral lobes, and 4.75 mm. wide at the genal angles. Notches in the posterior margin, which indicate the position of the posterior ends of the dorsal furrows, are 2.75 mm. apart. A cranidium from Highgate Falls is 7 mm. long and 5.5 mm. wide at the palpebral lobes.

Comparisons.—In this species the "smoothing out" of the cephalon is complete except for the retention of a faint elevation in the axial region, but the nuchal spine has been retained, not lost as in *Plethopeltis arenicola.* The steepness of the cheeks makes the head unusually narrow, a characteristic by which it can easily be recognized.

Horizon and locality.—My first acquaintaince with this little fossil was in 1910, when I found a perfect cephalon in a pebble in a conglomerate at St. Philip de Neri, about 30 miles southwest of Rivière de Loup, Quebec. This specimen was, unfortunately, a victim to the energy of the charwomen who periodically descended upon my office.

The cephalon now used as a holotype was collected many years ago by Jules Marcou from a pebble in one of the limestone conglomerates at Lévis, Province of Quebec, and is No. 1733 in the Museum of Comparative Zoology. Professors Schuchert and Dunbar collected a single cranidium in zone 2 of the Missisquoi formation at Highgate Falls, Vermont.

Plethopeltis lata Raymond.

Pl. 13, fig. 5.

Plethopeltis lata RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 418, Pl. 13, fig. 5.

Description.—Cranidium short, two-thirds as long as wide, and nearly uniformly convex. Glabella raised only slightly above the general surface. Dorsal furrows obsolete except as depressions on either side at the posterior margin. The fixed cheeks are strongly convex, continuing the curvature of the glabella, and not depressed below it as in many species of the genus. The eyes are situated in front of the middle, well down on the sides of the cranidium, and have small, narrow palpebral lobes. The occipital furrow is narrow, not deeply impressed on the axial region. The nuchal segment is narrow, with a low median tubercle which has the appearance of being a vestige of the spine possessed by many other species of the genus.

Measurements.—The type is 4 mm. long and 6 mm. in width between the tips of the fixed cheeks. The glabella is 2.5 mm. wide at the posterior end. Another specimen is 5 mm. long, 7.25 mm. wide, and the glabella is 3.5 mm. wide at the posterior end.

Comparisons.—This species is in many respects a miniature of *Plethopeltis arenicola,* from which it differs chiefly in the form of the nuchal segment and the position of the eyes. The glabella is less prominent than that of *Plethopeltis walcotti* or *Plethopeltis welleri,* and the nuchal segment is not drawn out into a spine.

Horizon and locality.—Nine cranidia of this species were found in zone 3, one in zone 2, and in zone 1 of the Missisquoi formation in the gorge at Highgate Falls, Vermont. Type in Yale University Museum.

Plethopeltis convergens Raymond.

Pl. 13, fig. 2.

Plethopeltis convergens RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 419, Pl. 13, fig. 2.

Description.—Cranidium elongate, moderately convex, tapering toward the front. Viewed laterally, the profile shows an even curvature, the greatest convexity being in the middle. Eyes with long, very narrow palpebral lobes situated about half-way to the front. There is no nuchal furrow behind the glabella, but a faint one crosses the fixed cheek. Close to the posterior margin, on the median line, is a minute tubercle which appears to be the only vestige of a median spine.

Measurements.—Length of cranidium 11 mm.; width at palpebral lobes 7 mm.; at posterior margin about 9 mm.

Horizon and locality.—One cranidium was collected from zone 3 of the Missisquoi at Highgate Falls, Vermont. Holotype in the Yale University Museum.

Genus **Stenopilus** Raymond.

The various species of Plethopeltis described on the preceding pages show gradations from the typical species, *Plethopeltis saratogensis,* with distinct dorsal and faint glabellar furrows, to species which have neither of these classes of furrows and culminate in a form, *Plethopeltis convergens,* which has progressed farther and lost the nuchal furrow as well, but retains the nuchal spine.

The genus Stenopilus is suggested to include those derivatives of Plethopeltis which have gone one step farther, and have lost not only the furrows but the nuchal spine as well. Since there are so many gradations present in the series it would be possible to put the type of Stenopilus as a species under plethopeltis. On the other hand, if only the extremes be considered, Plethopeltis and Stenopilus deserve generic separation.

The genotype is *Stenopilus pronus* Raymond.

Stenopilus pronus Raymond.

Pl. 13, figs. 6, 7.

Stenopilus pronus RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 420, Pl. 13, figs. 6, 7.

Description.—Cranidium half-oval in outline, strongly convex, the summit of the convexity being reached near the posterior end, so that the shield appears somewhat hump-backed. There is nothing to indicate the outline of the glabella, so completely is it merged with the general surface and all slopes are steeply convex. The eyes are situated about the middle of the head, and have long but very narrow palpebral lobes. The sharp bend in the curvature of the cranidium shows that in life the long axis of the head must have made an angle of about 120° with that of the body, so that the animal must have presented a rather grotesque appearance.

Measurments.—The holotype is 14 mm. long, 9 mm. wide at the palpebral lobes, and about 11 mm. wide at the posterior margin. Another cranidium is 17 mm. long, but a number are shorter than the type.

Horizon and locality.—Eight cranidia of this species were found in zone 3 of the Missisquoi at Highgate Falls, Vermont. Type in the Yale University Museum.

Stenopilus brevis, Raymond.

Pl. 13, fig. 9.

Stenopilus brevis RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 420, Pl. 13, fig. 9.

Description.—Cranidium small, short, convex, with steep frontal and lateral slopes. No glabellar, dorsal or occipital furrows present. Palpebral lobes either absent, or so narrow and ill-defined as to be unrecognizable. Fixed cheeks narrow. Surface punctate.

Measurements.—The holotype is 3.5 mm. long and 4.25 mm. wide at the posterior margin. Other cranidia are of about the same size or slightly smaller.

Comparisons.—The almost featureless, short, convex cranidium of this species cannot readily be confused with that of any other known trilobite. The practical loss of eyes is interesting, particularly as it does not seem to be accompanied by any fusion of fixed and free cheeks. This would seem to be the limit of variation from Plethopeltis in the direction of loss of furrows.

Horizon and locality.—Five cranidia were collected in zone 2 of the Missisquoi at Highgate Falls, Vermont, and are in the Yale University Museum.

Family CORYNEXOCHIDAE Angelin.

Subfamily *Corynexochinae* Raymond.

Genus **Corynexochus** Angelin.

Corynexochus juvenis Raymond.

Pl. 13, fig. 10.

Corynexochus juvenis RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 421, Pl. 13, fig. 10.

Description.—Cranidium small, about as long as wide. Glabella large, convex, expanding forward, extending to the front, bounded by narrow, sharp dorsal furrows. It begins to expand at the mid-length and there are faint traces of two pairs of glabellar furrows. Fixed cheeks depressed-convex, palpebral lobes small, situated at about the middle of the length, near the glabella but separated from the dorsal furrows by about their own width. Back of the eye the facial suture makes a smooth curve outward and backward to the posterior margin. In front it curves outward and then forward to the margin, leaving a depressed lappet on either side of the glabella. Surface smooth.

Measurements.—The cranidium (holotype) is 2 mm. long, 2 mm. wide at the palpebral lobes and 3 mm. at the back. The glabella is 1 mm. wide at the back and 1.5 mm. at the front.

Comparisons.—No representative of this genus has previously been found in strata younger than the Middle Cambrian. Its general form is exactly that of the genotype, *Corynexochus spinulosus* Angelin, but it has only faint glabellar furrows. Walcott (1916, p. 309, *et seq.*) has listed several Lower and Middle Cambrian species as belonging to this genus. This species rather closely resembles some of the Lower Cambrian forms.

Horizon and locality.—A single cranidium was obtained from zone 2 of the Missisquoi at Highgate Falls, Vermont, and is in the Yale University Museum.

Genus **Acheilus** Raymond.

Corynexochinae with expanding glabella, straight dorsal furrows, but no brim. Anterior glabellar furrows faint or absent; the other two pairs more prominent but short.

Genotype, *Acheilus marcoui* Raymond.

This genus is proposed for small trilobites with no brim, reduced cheeks, and a large prominent glabella which much resembles that of a Corynexochus or Bonnia, but which is shorter and has straight instead of curved sides. The species which is designated as the type is rather common in the boulders at Lévis, and another similar form is present at Highgate Falls. It appears to me that *Amphion ? matutina* Hall is also referable to this genus, but differs from all others except *Acheilus spicatus* in possessing a nuchal spine.

Acheilus marcoui Raymond.

Pl. 13, fig. 15.

Acheilus marcoui RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 422, Pl. 13, fig. 15.

Description.—Cranidium small, strongly convex, with narrow fixed cheeks. Glabella large, strongly convex, curved abruptly downward at the front. First glabellar furrows, obsolete; second pair short, faint, straight; third pair faint, running inward and then backward nearly or quite to the occipital furrow, isolating nearly quadrangular basal lobes. These furrows are shallow and are not seen on all specimens. Eyes large, situated midway in the length. The course of the facial suture is almost straight forward from the inner angle of the eye to the anterior margin, where it turns inward. It leaves only a narrow flattened fixed cheek along the side of the anterior portion of the glabella. Back of the eyes the suture turns diagonally outward and backward, cutting off small triangular fixed cheeks. The occipital furrow is narrow but deep on both axial and lateral lobes. The nuchal ring is flat, without pustule or spine.

Measurements.—Length of cranidium (holotype) 3.5 mm.; width at palpebral lobes 3.75 mm.; at posterior margin 4.25 mm.; width of glabella at back 2 mm., at front 2.75 mm.

Comparisons.—The general appearance of this trilobite reminds one of *Corynexochus capito* Walcott from the Lower Cambrian of Georgia, Vermont, but it lacks the lip-like brim of that species and the eyes are not so far from the glabella. Most of the other species of Corynexochus have a longer glabella.

Horizon and locality.—A rather common trilobite in some of the boulders of the limestone conglomerate at Lévis, Province of Quebec.

Holotype collected by Jules Marcou, now No. 1734 in the Museum of Comparative Zoology.

Acheilus macrops Raymond.

Pl. 13, figs. 11.

Acheilus macrops RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 423, Pl. 13, fig. 11.

Description.—Cranidium small, convex, with fixed cheeks reduced to but little more than the palpebral lobes. Glabella large, expanding forward, not high in front. First and second pairs of glabellar furrows short and straight, the first pair very faint and not present on all specimens; third pair deeper than the others, curved backward, but do not join the occipital furrow. Palpebral lobes large, diagonally placed, near the dorsal furrows at the anterior end, extending outward and backward nearly to the occipital furrow. In front of the eye the facial suture runs forward and inward, so that there is almost no fixed cheek beside the anterior part of the glabella. Back of the eye the fixed cheek is small and triangular. Occipital furrow narrow, nuchal ring narrow and convex. No occipital pustule or spine.

Measurements.—A cranidium (the holotype) is 2.25 mm. long and 2.75 mm. wide at the palpebral lobes.

Comparisons.—This species differs from *Acheilus marcoui* in having smaller fixed cheeks, larger palpebral lobes, and in having smaller and less completely isolated basal lobes on the glabella.

Horizon and locality.—A rather rare species in zones 1 and 3 of the Missisquoi at Highgate Falls, Vermont. Type in Yale University Museum.

Acheilus matutinus (Hall).

Amphion ? matutina HALL, 16th Ann. Rept. N. Y. State Cab. Nat. Hist., p. 22, Pl. 5A, fig. 6, 1863; Trans. Albany Inst., Vol. 5, p. 194, 1867. —WALCOTT, Smithson. Misc. Coll., Vol. 64, No. 3, p. 219, Pl. 26, figs. 8, 8a, 1916.

This species is not well known but the form of glabella, position of glabellar furrows, lack of brim and direction of the anterior portion of the facial suture are all as in Acheilus. The palpebral lobe is small, situated rather far from the glabella, and the presence of a nuchal spine distinguishes this from the two previous species.

Horizon and locality.—Lower beds of the Upper Cambrian at Trempealeau, Wisconsin, and the Eau Claire formation at Dresbach, Winona Co., Minnesota.

Acheilus ? blairi (Weller).

Ptychoparia blairi Weller, Pal. New Jersey, Vol. 3, p. 116, Pl. 1, fig. 10-13, 1902.

This species is referred to Acheilus with some doubt, since the glabella does not expand, but actually, as shown in the figure, contracts forward. The description states that it is parallel-sided. There is, however, very considerable resemblance to *Acheilus marcoui,* although the fixed cheeks are wider both in front of and behind the eyes.

Horizon and locality.—From the Upper Cambrian one-half mile north of Blairstown, New Jersey where it is associated with Plethopeltis.

Acheilus spicatus Raymond.

Pl. 13, fig. 12.

Acheilus spicatus Raymond, Proc. Boston Soc. Nat. Hist., 1924, Vol. 31, No. 4, p. 424, Pl. 13, fig. 12.

Description.—Cranidium minute, smooth, with a broad-based, sharp nuchal spine. Glabella very broad, expanding toward the front, separated from the cheeks by very narrow and lightly impressed dorsal furrows. There are three pairs of glabellar furrows, all short and but faintly impressed. The nuchal furrow is narrow, and the spine stands at an angle of about 150° with the surface of the glabella. Fixed cheeks narrow at the front, expanding backward, descending in a nearly flat slope from the glabella. Palpebral lobes not well preserved, apparently small.

Measurements.—Length of cranidium, including nuchal spine, 2.5 mm., width at back 2.5 mm.; length of glabella 2 mm., width at back 1.25 mm., at front 2 mm.

Comparisons.—This species differs from all others referred to the genus except *Acheilus matutinus* (Hall) in having a nuchal spine. From that species it is to be distinguished by its much fainter glabellar furrows, of which there are three instead of two pairs.

Horizon and locality.—A single specimen was obtained from zone 2 of the Missisquoi at Highgate Falls, Vermont, and is in the Yale University Museum.

Family Remopleuridae Corda.

Genus **Apatokephaloides** Raymond.

Remopleuridae similar to Apatokephalus, but with smaller eyes, glabella less expanded between the palpebral lobes, and with the facial sutures extending nearly straight forward from the eyes, so that the brim is not greatly extended laterally.

Genotype, *Apatokephaloides clivosus* Raymond.

Apatokephaloides clivosus Raymond.

Pl. 13, figs. 13, 17.

Apatokephaloides clivosus Raymond, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 425, Pl. 13, figs. 13, 17.

Description.—Cranidium short and wide, with its portion of the brim but slightly extended laterally. Glabella elongate, depressed-convex, expanded between the eyes. There are two pairs of glabellar furrows, the first joining the dorsal furrows just back of the anterior end of the palpebral lobes, their direction being diagonally backward and inward. They are short but deep. The second pair do not reach the dorsal furrows and are curved depressions which have various shapes in different specimens. The palpebral lobes are long, situated about midway in the head, separated from the glabella by a narrow furrow only. Posterior fixed cheeks large, extending out well beyond the eyes. Occipital furrow narrow, continuous across axial lobe and cheeks. Occipital ring wide, without median pustule. Brim of medium width, nearly flat, with a narrow raised border which usually is broken off. No specimen has been seen showing the row of pits inside the border which characterizes species of Apatokephalus. The surface is covered with low rounded pustules.

Two imperfect pygidia are referred to this species because of their general resemblance to the pygidia of Apatokephalus. Pygidium wider than long, with four pairs of short, incurved marginal spines. The axial portion of both specimens is too badly preserved to show anything of value. There are at least three rings, and there are very short spines immediately behind the axial lobe. Each pleural lobe has a furrowed rib corresponding to the marginal spine. The surface is thickly covered with low rounded pustules.

Measurements.—Length of cranidium (holotype) 6 mm.; width at palpebral lobes 5 mm., at posterior margin 10 mm.; length of glabella 4 mm., width at axial lobe 3.25 mm. A large pygidium is 7 mm. long and about 22 mm. wide on the anterior margin.

Comparisons.—This species differs from *Apatokephalus finalis* (Walcott, 1884, p. 89, Pl. 12, figs. 12, 12a) chiefly in that the facial sutures turn more directly forward in front of the eyes, thus much reducing the amount of the brim pertaining to the cranidium. The row of pits inside the border is also lacking, and the first glabellar furrows are generally obliterated, although one specimen shows a trace of them. The pygidia are much alike.

The type of Apatokephalus, *Apatokephalus serratus* (Sars and Boeck) has one more pair of spines on the pygidium, and a cranidium much like that of *Apatokephalus finalis*. The eyes are much smaller and farther forward in the present species than in either of the others mentioned.

Horizon and locality.—This is a fairly common trilobite in zone 3 of the Missisquoi at Highgate Falls, Vermont. Two cranidia were found in zone 1. Holotype (a cranidium) and paratype (a pygidium) in Yale University Museum.

Apatokephaloides inflatus Raymond.

Apatokephaloides inflatus RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 426.

Description.—This species differs from the preceding in having a more convex glabella, narrower brim, and in having the glabellar furrows reduced to two pairs of pits which do not connect with the dorsal furrows. The facial sutures have the same course as in *Apatokephaloides clivosus* and the palpebral lobes are large, situated adjacent to the dorsal furrows, and about midway in the length.

Measurements.—Length of cranidium of holotype 7 mm., width at posterior margin 7 mm.; length of glabella 5 mm., width at the back 5.5 mm.

Horizon and locality.—A rare species in zones 2 and 3 of the Missisquoi at Highgate Falls, Vermont.

The holotype, a cranidium, is in the Yale University Museum.

Family ASAPHIDAE Salter.

Subfamily *Ogygiocarinae* Raymond.

Niobe ? sp. ind.

A single fairly well-preserved pygidium suggests reference to Niobe, but in the absence of the cranidium a positive identification is not possible. The outline is regularly rounded, the length more than one-half the width, and the surface gently convex. The axial lobe is narrow, less than one-third the total width, moderately convex. The anterior two-thirds of its length shows six rings; the posterior third has been broken away. The pleural lobes have three pairs of short ribs, corresponding with the first three rings on the axial lobe. The greater part of the surface is smooth, and there is a wide concave border.

Measurements.—Length 22 mm.; width about 32 mm.; length of axial lobe 17 mm.; width at front about 7 mm.

Comparisons.—This pygidium is not unlike that of *Niobe morrisi* (Billings), a species found in the Normanskill of Newfoundland. It is not quite so broad, the axial lobe is relatively shorter, and the ribs are neither so long nor so broad, although in both cases there are three pairs.

Niobe has not been found in the American Beekmantown, although it may be discovered at any time, since it is common enough in the Ceratopyge zone in Europe. I do not know any European species with so few and short ribs.

Horizon and locality.—A single pygidium was found in a boulder in a limestone conglomerate in the Georgia formation about five miles north of Highgate Center, Vermont.

Genus **Bellefontia** Walcott.

Smithson. Miscl. Colls., 1924, Vol. 75, No. 2, p. 54.

Walcott has recently published this generic name proposed by Dr. Ulrich for Asaphidae with a short pygidium and very narrow axial lobe. The following species falls perhaps more naturally into Bellefontia than into Asaphellus, under which it was originally described.

Bellefontia obtecta Raymond.

Pl. 13, figs. 14, 18.

Asaphellus obtectus RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 428, Pl. 13, figs. 14, 18.

Description.—Known from pygidia only. Pygidium short and wide, rounded in outline. Axial lobe narrow, less than one-third the total width, not greatly elevated, but surrounded by deep dorsal furrows. There is a single ring behind the anterior half-ring. The pleural lobes are smooth, except for an anterior intramarginal furrow, and slope to a narrow concave margin. The doublure is very narrow.

Associated with the pygidia is a single hypostoma, which is largely the basis for the generic reference. Its posterior margin is straight, the lateral and anterior margins gently convex, so that the entire organ is subquadrate. The brim is narrow and concave, the body gently convex, and the maculae small, connected directly with the lateral furrows.

Measurements.—No pygidium is complete, and estimated measurements are indicated by the word "about." The holotype is 16 mm. long and 31 mm. broad; another specimen is 12 mm. long and about 24 mm. wide; the axial lobe is 11.5 mm. long and 5 mm. wide at the front. A larger pygidium is a little more than 18 mm. long. A small one is 9 mm. long, about 18 mm. wide, and the axial lobe is about 4 mm. wide at the front. The hypostoma is 5.5 mm. long and 5 mm. wide.

Comparisons.—The hypostoma found with these pygidia resembles that of *Asaphellus homfrayi* (Salter), the type of the genus, and certainly belongs to a member of the Ogygiocarinae. If it belonged to one of the trilobites whose pygidia occur in the same layers, as it probably did, then the generic reference must be within the subfamily indicated.

Asaphellus homfrayi Matthew, var. (1903, p. 232, Pl. 18, fig. 10a-10e) from Cape Breton has an hypostoma and pygidium almost identical with those of the present species. Matthew's species is, however, not the same as Salter's *Asaphellus homfrayi*, and if the cephalon of the form found in Vermont should prove to be like that of the trilobite from Cape Breton, the name now proposed could be used for specimens from both localities.

Horizon and locality.—Several fragmentary pygidia and one hypostoma were found at the base of the Georgia formation at a locality 0.5 miles south of the Canadian border, 0.5 miles west of Rock River, and about 5 miles north of Highgate Center, Vermont.

Hemigyraspis, sp. ind.

An exceedingly badly preserved thorax and pygidium on the surface of a piece of sheared limestone indicate the presence of some sort of an asaphid in the Highgate limestone. Enough of the outline of the pygidium can be made out to show that it was short and wide, thus suggesting Hemigyraspis, but it is quite impossible to make a positive determination. Seven or possibly eight thoracic segments can be counted, and two of them have diagonal furrows and rounded, blunt terminations as in the Asaphidae. The axial lobe appears to be somewhat more than one-third the total width. Six segments together are about 30 mm. long, and the width at the middle of the thorax would seem to have been about 60 mm. It is impossible to get any accurate measurements of the pygidium, somewhat less than half of which is preserved in a much flattened condition, but one may judge that it had been about 60 mm. wide and 35 mm. long.

Horizon and locality.—This specimen was found associated with *Pilekia extenuata* and *Leiostegium puteatum* in the Highgate limestone two miles north of Highgate Center, Vermont.

Family Styginidae Raymond.

Genus **Leptopilus** Raymond.

Cephalon strongly convex, narrow, without depressed border. Glabella short, parallel-sided. Eyes large, far back, and close to the dorsal furrows.

Genotype, *Leptopilus declivis* Raymond.

This genus is erected for a little trilobite which much resembles an agnostid, but which bears large eyes far back and close to the dorsal furrows. The facial sutures are those of Stygina, hence the species is tentatively placed in the family with it. The very short parallel-sided glabella is not, however, at all like the long, expanding one of Stygina or Holometopus.

Leptopilus declivis Raymond.

Pl. 13, fig. 20.

Leptopilus declivis Raymond, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 430, Pl. 13, fig. 20.

Description.—Cephalon narrow, convex, agnostiform, without marginal furrow or elevated border. Glabella short, about half the whole length, narrow, apparently without furrows. Dorsal furrows narrow, becoming shallow forward, and joining in front of the glabella. The occipital furrow is narrow, rather deep, and extends half-way down the sides. Eyes large, situated far back and near the dorsal furrows; an ocular ridge runs forward from each to near the front of the glabella. Free cheeks wide, standing at a high angle on the convex sides of the cephalon. Each bears a short acute genal spine.

In front of the eyes the facial sutures turn outward down the slope of the cheeks, then converge again, being very close to the margin in the later part of their course, and meeting at an obtuse angle in the middle of the front. Back of the eyes they turn directly outward till they reach a point half-way down the slope of the cheeks, then turn abruptly back to the margin. Surface smooth.

Measurements.—The cephalon (holotype) is 5 mm. long, 2.75 mm. wide at the palpebral lobes, and 5.25 mm. wide at the posterior margin. The glabella plus the nuchal segment is 3 mm. long, and 1.5 mm. wide. Each eye is about 1.5 mm. long.

Comparisons.—The surface of this specimen is somewhat weathered, so that neither the eyes nor the sutures show distinctly. It has, therefore, very much the same appearance as *Idiomesus tantillus*, and might also be mistaken for an agnostid. The most nearly allied species of which I am cognizant is *Holometopus angelini* Billings, a small trilobite which was described from "Limestones No. 2" at Lévis. The glabella is, however, much shorter than that of *Holometopus angelini*, and the whole cephalon is narrower. *Holometopus limbatus* Angelin, the type of the genus, has a still longer glabella.

Horizon and locality.—A single cephalon now in Yale University Museum, was found in the lower part of the Highgate limestone north of Highgate, Vermont.

Family Dikelocephalidae Miller.

Subfamily *Dikelocephalinae* Beecher (emend. Walcott).

Walcott (1914, p. 346) has discussed the American species of this branch of the Dikelocephalidae, and proposed a number of new genera. Dikelocephalus Owen (emend. Walcott) "appears to be distinct from all other genera by the broad flattened border of its cephalon, large eyes placed well back, large, broad subquadrangular glabella with posterior furrow, and large wide pygidium with broad flattened border." Genotype *Dikelocephalus minnesotensis* Owen.

Saukia Walcott "has a narrow frontal border about the cephalon and a glabella proportionately more elongate than in Dikelocephalus. The pygidium of Saukia is less expanded and proportionately more elongate than that of Dikelocephalus." Genotype, *Dikelocephalus lodensis* Whitfield.

Conokephalina Broegger "has a somewhat similiar form to that of Saukia, but the strong transverse posterior glabellar furrow of Saukia, and the absence of a clearly marked frontal limb in advance of the glabella serve to distinguish the cranidium of Saukia. The pygidium associated with *Conokephalina ornata* is transverse with a spinose margin, while that of Saukia is nearly as long as broad, and the margin is unbroken by spines." Genotype *Conokephalina ornata* Broegger.

Osceolia Walcott "is characterized by its concave limb, elongated palpebral lobes; narrow fixed cheeks and transverse pygidium with its anterior segment extended beyond the margin as a [pair of] long strong spine[s]." Genotype, *Dikelocephalus osceola* Hall.

Calvinella Walcott "is most like Saukia, from which it differs in form of glabella, presence of a strong occipital spine, and proportionately more elongate pygidium." Genotype, *Dikelocephalus spiniger* Hall.

Omitting Conokephalina, which as will be shown, is probably not known in the American Upper Cambrian fauna, the remaining four genera may be divided into two groups, each with two genera.

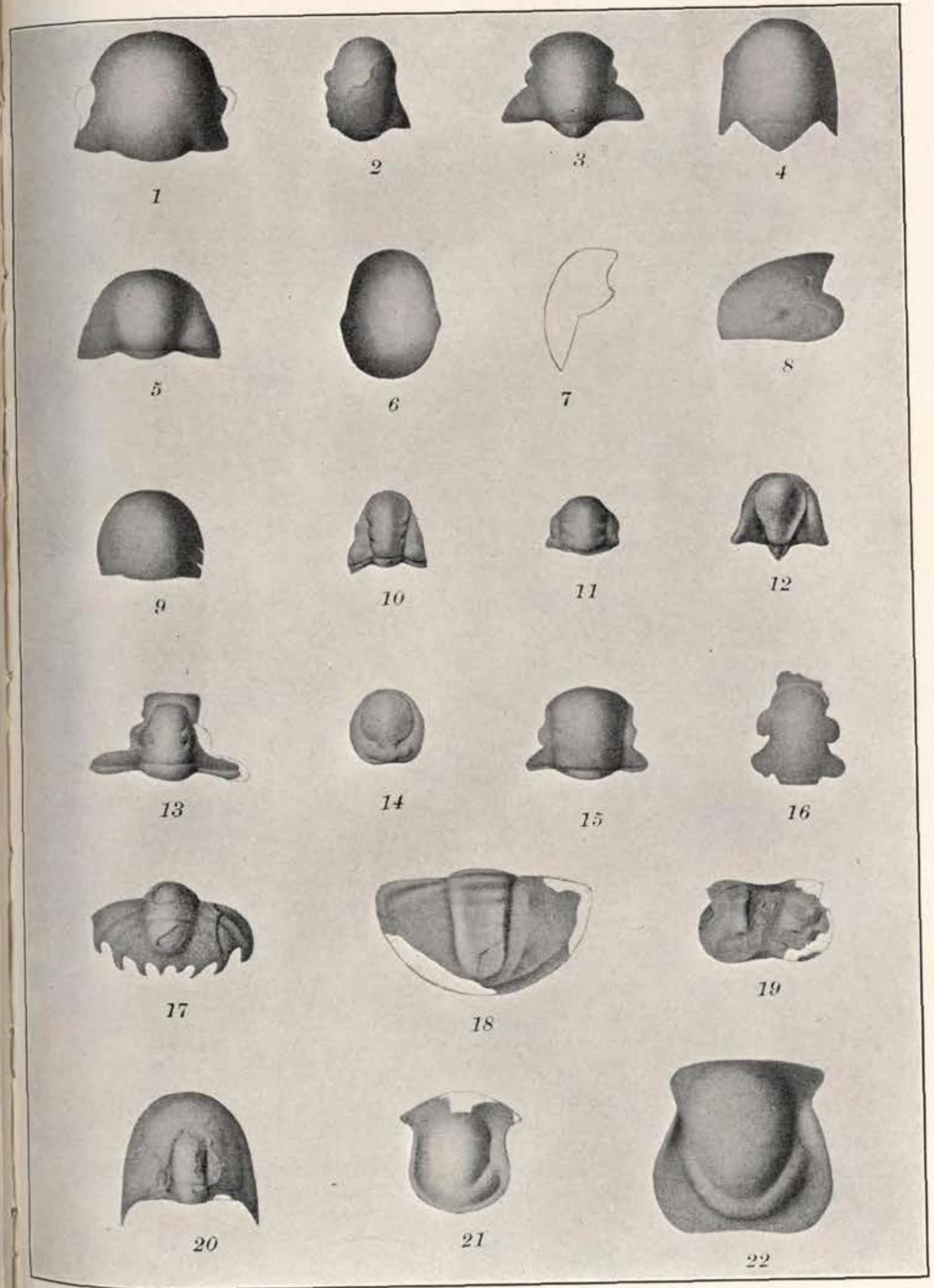
Dikelocephalus and Osceolia both have a wide concave or flat border in front of the glabella; Saukia and Calvinella have only a narrow furrow and elevated border at the front. The types of Dikelocephalus and Osceolia have one pair of marginal spines on the pygidium, which is broad. Saukia and Calvinella have narrow pygidia with smooth margins. Dikelocephalus has a shorter glabella than Osceolia and usually is of greater size. Calvinella is essentially a Saukia with a long occipital spine.

Conokephalina was based on *Conocephalites ornatus* Broegger, a small trilobite from the Middle Cambrian at Krekling, Norway. Walcott has agreed provisionally with Broegger in referring *Dikelocephalus misa* Hall to this genus and has also suggested that *Dikelocephalus inexpectans* Walcott, *Dikelocephalus cristatus* Billings, *Dikelocephalus iole* Walcott, and *Dikelocephalus megalops* Billings may be placed in it. He has also described a new species as *Conokephalina whitehallensis*.

The chief peculiarity of *Conokephalina ornata* as a dikelocephalinid, is that the posterior glabellar furrows do not unite at

Fig. 1. *Plethopeltis arenicola* Raymond. × 1.
Fig. 2. *Plethopeltis convergens* Raymond. × 1 1/3.
Fig. 3. *Plethopeltis laevis* Raymond. × 3 1/3.
Figs. 4, 8. *Plethopeltis angusta* Raymond. × 4.
Fig. 5. *Plethopeltis lata* Raymond. × 2 1/3.
Figs. 6, 7. *Stenopilus pronus* Raymond. × 1 1/3.
Fig. 9. *Stenopilus brevis* Raymond. × 3 1/3.
Fig. 10. *Corynexochus juvenis* Raymond. × 4.
Fig. 11. *Acheilus macrops.* Raymond. × 4.
Fig. 12. *Acheilus spicatus* Raymond. × 4.
Figs. 13, 17. *Apatokephaloides clivosus* Raymond. × 2.
Fig. 14. *Bellefontia obtecta* Raymond. × 2.
Fig. 15. *Acheilus marcoui* Raymond. × 4.
Fig. 16. *Asaphellus*, sp. ind. From the Georgia, north of Highgate Center. × 1 1/3.
Fig. 18. *Bellefontia obtecta* Raymond, the holotype. × 1.
Fig. 19. *Asaphellus*, sp. ind. From the Georgia, north of Highgate. × 1.
Fig. 20. *Leptopilus declivis* Raymond. ×3 1/3.
Fig. 21. *Saukia pepinensis* (Owen). × 2.
Fig. 22. *Dikelocephalus insolitus* Raymond. × 1.

PLATE XIII.



the median line ("sulcis utrinque 3, posterioribus obliquis, anterioribus sulco occipitali parallelis," Broegger) but are strongly oblique. The wide pygidium has three pairs of short spines.

Dikelocephalus misa Hall has the posterior furrows joined to form a deep cross-furrow, and the pygidium usually attributed to it is spineless. It seems that the species is much more closely allied to Saukia than to Conokephalina and, in fact, I would not know by what characteristics it could be separated from the former genus. It has, it is true, one peculiar feature, which is a narrow furrow parallel to the front of the anterior part of the circum-glabellar furrow, dividing the brim into two narrow ridges. Otherwise it is a quite typical Saukia.

Dikelocephalus megalops Billings (1865, p. 403, fig. 380) also has a continuous furrow across the posterior part of the glabella and so cannot be a Conokephalina. It is made the type of a new genus on a later page of this work.

Dikelocephalus inexpectans Walcott (1884, p. 90, Pl. 1, fig. 10) is based on a small cranidium from the lowest Ordovician. It agrees with Conokephalina in that the eyes are large and near the dorsal furrows, but shows no other characteristics of the Dikelocephalinae. There are only two pairs of slightly indented furrows, and the sutures pursue a totally different course from those of Conokephalina, turning outward and meeting the margin on a line drawn across the anterior ends of the eyes. The sutures alone would exclude the trilobite from this subfamily.

Dikelocephalus iole Walcott, which is referred only doubtfully to Conokephalina, is a small trilobite which may belong to the Dikelocephalidae, but is excluded from Conokephalina by the fact that the two pairs of glabellar furrows do not reach the dorsal furrows. This species has now been made the type of the genus Tostonia by Walcott.

Conokephalina whitehallensis Walcott (1912, p. 269, Pl. 44, fig. 9-11a) is remarkably similar to *Conokephalina ornata,* but the associated pygidium lacks marginal spines. The cranidium is very similar to that of young specimens of *Saukia misa,* but the pygidium is not of that genus, and is much more like that of a Ptychoparia. The proper generic allocation awaits fuller knowledge of the species.

Genus **Dikelocephalus** Owen.

Dikelocephalus insolitus Raymond.

Pl. 13, fig. 22.

Dikelocephalus insolitus RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 443, Pl. 13, fig. 22.

Walcott states in regard to the genus Dikelocephalus: "It does not occur in the St. Lawrence valley of Canada, but fragments of what may be a species of the genus occur in the Champlain valley in Franklin County, northwestern Vermont, both in the Upper Cambrian limestone (one mile southwest of Highgate Falls) and the superjacent limestone conglomerate." Professors Schuchert and Dunbar likewise found fragments which are probably referable to Dikelocephalus, but among them only a pair of hypostomata are sufficiently well preserved to be of any value. Ordinarily I should not give a name to a species based upon the hypostoma only, but since it is unlikely that the shield can be definitely associated with a dorsal test in the early future, it will be convenient to have a name for this elusive species.

Very little is known of the hypostomata of dikelocephalids. Hall figured three fragmentary ones of *Dikelocephalus minnesotensis* and one of *Saukia pepinensis* (1863, Pl. 9, figs. 4, 9, 10; Pl. 11, fig. 1). Walcott also figured three of *Dikelocephalus minnesotensis* (1914, Pl. 61, figs. 3, 7; Pl. 62, fig. 5) and one of *Dikelocephalus harti* (1912, Pl. 44, fig. 4). Hall gives the following descripton of the hypostoma of *Dikelocephalus minnesotensis:* "Hypostoma broad; the body convex and subcircular or very broadly oval, with margins expanded and furrowed near their antero-lateral angles. In small specimens, there is a minute node near each anterior angle." In reading this, the terms anterior and posterior should be reversed.

Combining the information afforded by Hall's and Walcott's figures, it appears that the hypostoma of *Dikelocephalus minnesotensis* is roughly rectangular, wider than long, the posterior border with a broad shallow median emargination. The body is approximately circular with rather deep lateral furrows, the maculae convex, circular or oval, with diagonal furrows between them and the body. The anterior end has a flattened border.

Description.—The hypostoma of *Dikelocephalus insolitus* is approximately square, with rounded angles, and a straight instead of emarginate posterior outline. The body is oval, the maculae elongate, narrow, obliquely placed, standing above a broad flat posterior brim. The surface is covered with sharp, irregular striae which are more or less parallel to the margins.

Measurements.—Length 12.5 mm.; greatest width 13.5 mm. The larger specimen is 14 mm. long and 15 mm. wide.

Comparisons.—It would appear that the hypostoma of Dikelocephalus much resembles that of Niobe among the Asaphidae, but is much less deeply emarginate than that of most of the species of that genus. The hypostoma of *Saukia pepinensis* is quite different from that of either of the species of Dikelocephalus. Instead of being wider than long it is longer than wide, the posterior margin is curved outward, instead of being straight or emarginate and there is no flat brim, but a narrow, wire-like, elevated border. A specimen in the Museum of Comparative Zoology is 8 mm. long and 7 mm. in greatest width—except at anterior margin—(see Pl. XIII, fig. 21). If the hypostomata of other species of Saukia are of this same type, there is additional reason to separate the genus from Dikelocephalus.

As noted above, the hypostoma of *Dikelocephalus harti* is known, and it is very like that of *Saukia pepinensis*. Is *Dikelocephalus harti* a real Dikelocephalus? According to Walcott, Dikelocephalus is to be restricted to those species having a relatively short glabella and a concave or flat brim. *Dikelocephalus harti* has a long glabella and a convex brim. The cephalon and pygidium of Dikelocephalus are short and broad, those of Saukia long and narrow. The cephalon and pygidium of *Dikelocephalus harti* have proportions much more nearly like those of *Saukia lodensis* than those of *Dikelocephalus minnesotensis*. In fact, *Dikelocephalus harti* is exceedingly like *Saukia crassimarginata* in proportions and many other characteristics. It is, therefore, much more likely that *Dikelocephalus harti* is a Saukia than that two kinds of hypostomata are found within the genus Dikelocephalus.

Horizon and locality.—*Dikelocephalus insolitus* is so far known only from zone 1 of the Missisquoi at Highgate Falls, Vermont, and the type is in the Yale University Museum.

Genus **Saukia** Walcott.

Saukia lodensis (Whitfield).

Dikelocephalus lodensis WHITFIELD, Ann. Rept. Wisconsin Geol. Survey for 1879, p. 51, 1880; Geol. Wisconsin, Vol. 4, p. 188, Pl. 10, fig. 14; p. 341, Pl. 27, fig. 12, 13, 1882.—CHAMBERLIN, Geol. Wisconsin, Vol. 1, p. 130, text-figs. 16, 16a, b, 1883.

Saukia lodensis WALCOTT, Smithson. Misc. Coll., Vol. 57, pp. 373, 379, Pl. 65, fig. 1-3, 1914.

A single partially preserved cranidium appears to represent this species. About two-thirds of the glabella, anterior border, and the neck-ring are preserved. All these parts are covered with fine pustules. There are two pairs of glabellar furrows, the second pair uniting to form a complete cross-furrow, the first pair separated by only a short interval. Both pairs turn backward where they leave the dorsal furrows, then become parallel to the neck-furrow, as in *Saukia lodensis*. The form differs from good specimens of that species chiefly in that the frontal border is not so much depressed below the level of the top of the glabella. This may of course be due to distortion.

The pustulose surface of this specimen suggests *Ptychaspis speciosa* (Walcott). The glabella is not, however, so convex as in that species nor are the anterior glabellar furrows so distinct; the anterior border particularly is not turned downward as in Ptychaspis.

Measurements.—Length of cranidium 12 mm.; width of glabella at back about 10 mm., at front about 8 mm.

Horizon and locality.—Found in zone 3 of the Missisquoi at Highgate Falls, Vermont. The species is characteristic of the St. Lawrence formation in Wisconsin.

Saukia stosei Walcott.

Saukia stosei WALCOTT, Smithson. Misc. Coll., Vol. 57, No. 13, p. 384, Pl. 69, fig. 3-5; Pl. 70, figs. 12, 12a, 1914.

Two imperfect cranidia seem to represent this species, the only difference noted being that the eye appears to be slightly nearer the dorsal furrows in the specimens from Vermont than in the originals. The glabella is evenly convex, tapers a little forward, and has three pairs of furrows, the third pair continuous, the two others not united at the inner ends. A narrow concave brim separates the front of the glabella from a very narrow elevated border. What fragments of test remain have a granulose and punctate surface.

Measurements.—Length of cranidium 12 mm.; width at palpebral lobes about 14 mm.; width of glabella at back 9.5 mm., at front 8 mm.

Comparisons.—*Saukia stosei* is chiefly characterized by the combination of a glabella retaining all three pairs of glabellar furrows with a narrow concave brim edged by a very narrow convex border. Most of the species of this genus have the border wider than the furrow—in this one the reverse obtains.

Horizon and locality.—The original locality for this species was in the Conococheague limestone (near top of Upper Cambrian), northwest of Scotland Station, Franklin Co., Pennsylvania. Two cranidia were found in zone 3 of the Missisquoi at Highgate Falls, Vermont.

Saukia dunbari Raymond.

Pl. 14, fig. 7.

Saukia dunbari RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 437, Pl. 14, fig. 7.

Description.—This species is represented by an incomplete cranidium only. The glabella is large, evenly convex and tapers rapidly toward the front. The posterior glabellar furrows are deep and continuous across the glabella, nearly parallel to occipital furrow. The second pair are lightly impressed, but distinct, each extending about one-third the way across the glabella, nearly parallel to the third pair. The first pair are very faint, but nearly as long as the second. Their course is parallel to the occipital furrow.

The dorsal furrows are shallow, and rather narrow, especially at the front. The palpebral lobes are also narrow, situated close to the dorsal furrows. Most of the brim is broken away, but there appears to have been a narrow convex border at the front of the cranidium. The occipital segment is wide and convex. The surface is granulose.

Measurements.—Length of cranidium (incomplete at front) 17 mm.; width at palpebral lobes 18 mm.; length of glabella 12.5 mm., width at occipital furrow 13 mm., width at front 9.5 mm.; length of palpebral lobe 5 mm.

Comparisons.—The shape of the glabella of this species suggests *Saukia misa* (Hall) but the eyes are farther forward, and it lacks the peculiar doubly ridged brim of that species. *Dikelocephalus megalops* Billings is also suggested, but apparently the rim was separated from the front of the glabella by a narrow furrow only. Comparison may also be made with *Saukia marica* Walcott, that species having, however, the eyes much farther from the dorsal furrows.

Horizon and locality.—A single cranidium was collected from zone 3 of the Missisquoi at Highgate Falls, Vermont, and is in the Yale University Museum.

Subfamily *Richardsonellinae* Raymond.

Genus **Richardsonella** Raymond.

Among the species of "Dikelocephalus" described by Billings from the boulders at Lévis are two, *Dikelocephalus megalops*, and *D. cristatus*, which have more or less similarity to the genus to which they were assigned, but differ from it in one important particular. The course of the suture, in front of the eyes, is not first outward and then inward, but continues outward directly to the margin. As a result, that portion of the brim which belongs to the cranidium has angular instead of rounded lateral margins. Besides this feature, in which they differ from all other Dikelocephalinae, these species have, just inside the elevated border of the brim, a row of more or less conspicuous pits.

These species show a remarkable diversity in glabellar furrows. *Dikelocephalus megalops* has the typical furrows of the Dikelocephalinae, whereas *D. cristatus* has absolutely no trace of glabellar furrows.

Walcott (1914, p. 350-352) has referred *Dikelocephalus megalops* to Conokephalina, and *D. cristatus* with doubt to Conokephalina. The course of the facial suture in front of the eye shows that neither of these species belongs to that genus. On the other hand, the general form and the peculiar row of depressions show that the species belong to one group, and the glabellar furrows of *Dikelocephalus megalops* indicate that group to be the Dikelocephalidae. It is, therefore, necessary to erect a new genus, which I propose to call Richardsonella, in remembrance of Mr. James Richardson's excellent work on the "Quebec Group."

As genotype, *Dikelocephalus megalops* Billings may be selected.

Since the above went to the printer, Dr. Walcott has described a trilobite from British Columbia as *Hungaia billingsi* (Smithsonian Miscl. Colls., 1924, Vol. 75, p. 37, fig. 7). This form has a cranidium which in many ways resembles that of Richardsonella, but the pygidium is entirely different from the one supposed to belong to that genus (see Billings, Pal. Foss. Canada, 1865, Vol. 1, p. 403, figs. 382, 383). The similarities of the cephala make it necessary to point out that in Richardsonella the sutures in front of the eyes follow a course which deviates by only 30° to 40° from the axis, whereas those of *Hungaia billingsi* approximate 90°. As a result, the portion of the cephalon in front of the glabella is much wider in the species just mentioned than in Richardsonella. *Dikelocephalus oweni* Billings and possibly *D. planifrons* Billings, are probably congeneric with *Hungaia billingsi* rather than with *Richardsonella megalops.*

Richardsonella megalops (Billings).

Dikelocephalus megalops BILLINGS, Canadian Nat. and Geol., Vol. 5, p. 311, fig. 9, 1860; Geol. Canada, p. 236, fig. 257, 1863; Pal. Foss. Canada, p. 403, fig. 380, 1865.—MATTHEW, Trans. Roy. Soc. Canada, Vol. 10, Sec. 4, p. 11, footnote, 1893.

This species has a glabella of the form typical of Saukia, three pairs of glabellar furrows, the hinder pair of which are continuous with one another, very large eyes close to the dorsal furrows, and a narrow convex border on a rather narrow brim. Were it not for the course of the facial sutures, the pits inside the border, and the striations on the brim, one would consider this a typical Saukia.

Horizon and locality.—This species has been found only in the boulders in the limestone conglomerate at Lévis, Province of Quebec.

Richardsonella tribulis (Walcott).

Dikelocephalus tribulis, WALCOTT, Smithson. Misc. Coll., Vol. 57, No. 9, p. 274, Pl. 44, figs. 8, 8a, 1912; *ibidem*, No. 13, p. 378, Pl. 63, figs. 8-10, 10a, 1914.

I have not seen a specimen of this species, but the photographic figure shows a brim with the striations and pits characteristic of Richardsonella. The glabella has a continuous posterior furrow, and one pair which do not meet at the inner ends. The specimen is too incomplete to show the course of the facial suture.

Horizon and locality.—A rare species in the Hoyt limestone, 4 miles west of Saratoga, New York.

Richardsonella germana Raymond.

Pl. 14, fig. 3.

Richardsonella germana RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 440, Pl. 14, fig. 3.

Description.—Known from an imperfect cranidium only. Cranidium short, depressed-convex, the front an arc of a circle of large radius.

Glabella gently and evenly convex, expanding slightly toward the front, the sides nearly parallel. The occipital furrow is faint, as are the two pairs of glabellar furrows. These are peculiar, as the outer ends do not reach the dorsal furrows, but the inner ends are united, so that they produce a pair of bow-shaped depressions, concave forward. The second pair almost reach the dorsal furrows. The brim is narrow, with a raised border as wide as the concave portion behind it. The pits inside the border are very small, and no striations are present. The palpebral lobes are not well preserved, but appear to be large and close to the narrow dorsal furrows. The specimen retains the test, which is smooth, except for irregular, fine striations on the border.

Measurements.—The cranidium of the holotype is 12.5 mm. long, and about the same in width at the palpebral lobes. The glabella plus the occipital ring is 10 mm. long.

Comparisons.—This species is perhaps most closely allied to *Richardsonella belli* (Billings) but has a narrow brim, smaller pits, a more nearly rectangular glabella, and more continuous although equally faint glabellar furrows.

Dikelocephalus iole Walcott (1884, p. 43, Pl. 10, fig. 19) has a glabella which strongly resembles that of *Richardsonella germana.*

Horizon and locality.—A single cranidium was collected in zone 3 of the Missisquoi at Highgate Falls, Vermont, and is in the Yale University Museum.

Richardsonella cristata (Billings).

Dikelocephalus cristatus BILLINGS, Canadian Nat. and Geol., Vol. 5, p. 236, fig. 258, 1860; Pal. Foss. Canada, Vol. 1, p. 404, fig. 381, 1865.—MATTHEW, Trans. Roy. Soc. Canada, Vol. 10, sect. 4, p. 11, footnote, 1893.

This species is chiefly remarkable for the complete obliteration of the glabellar furrows. A small cranidium in the Museum of Comparative Zoology is of interest because it shows the facial sutures and the brim to be of the same form as those of *Richardsonella oweni.*

Horizon and locality.—This trilobite has so far been found in the pebbles of the conglomerate at Lévis only.

Richardsonella laeviuscula sp. nov.

Richardsonella iole RAYMOND (non Walcott), Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 441.

Through the kindness of Dr. Resser I have been able to see the original specimens of *Dikelocephalus iole,* a species which has recently been made the type of a new genus, Tostonia, by Walcott.

Although very like *Tostonia iole*, the specimens which I referred to that species in the previous edition of this paper differ in having longer posterior glabellar furrows and in having a row of obscure pits along the brim. The glabella is depressed convex, nearly smooth, and has only two pairs of furrows, neither of which reach the dorsal furrows. The glabella is long, the brim narrow and turned somewhat downward, the border being but slightly elevated. The palpebral lobes are large, slightly farther from the glabella than those of Walcott's original specimen.

Measurements.—The cranidium is 6.5 mm. long; the glabella is 4.5 mm. long and 3.5 mm. broad at the back.

Horizon and locality.—The single specimen was found in zone 1 of the Missisquoi at Highgate Falls, Vermont.

Subfamily *Hungaiinae* Raymond.

Genus **Hungaia** Walcott.

Hungaia WALCOTT, Smithson. Misc. Coll., Vol. 57, No. 13, p. 351, 1914 (name published, with a reference to a published description and figure).

The name of this genus has been published, and since but one species, *Dikelocephalus magnificus* Billings (1865, p. 400, fig. 376) has been assigned to it, no description has been necessary.

Hungaia magnifica is a remarkable trilobite, the cranidium of which is very much like that of Dikelocephalus, except for its vestigial furrows. The pygidium, however, ends in four pairs of short flat spines, and is, superficially at least, quite unlike that of Dikelocephalus. *Dikelocephalus minnesotensis* and Osceolia, however, each have one pair of flat spines on the pygidium. Dikelocephalus, it is true, has numerous pairs of ribs on the pleural lobes, but Osceolia shows only three, one less than in Hungaia.

Since the cranidium is very like that of the Dikelocephalidae, and the pygidium is not such as to prevent reference to that family, it seems that it is best to place the form there. It cannot, however, be placed in the same subfamily with any of the other genera, and it is necessary to erect for it a new one, the Hungaiinae, which shall contain dikelocephalids with short glabella and broad concave or flat brim, and a pygidium with no rim and the ribs ending in flat spines.

Hungaia magnifica (Billings).

Dikelocephalus magnificus BILLINGS, Canadian Nat. and Geol., Vol. 5, p. 307, fig. 5, 1860; Geol. Canada, p. 235, figs. 255a, b, 1863; Pal. Foss. Canada, Vol. 1, p. 399, fig. 376, 1865.—MATTHEW, Trans. Roy. Soc. Canada, Vol. 10, Sec. 4, p. 11, 1893.—FRECH, Lethaea Geog., Pal., Vol. 2, Pl. 16, figs. 18a, b, 1897.

Apatokephalus magnificus BROEGGER, Nyt Mag. f. Naturvid., Vol. 36, p. 175, fig. 10, p. 184, 1897.

This species is too well known to need redescription, but it should be pointed out that the radial ridges which cross the brim are not so prominent on specimens as the figure would indicate, and that the glabella is proportionately longer and narrower. There is also a rather prominent tubercle on the median line, just in front of the neck-furrow.

The pygidium was incorrectly described and figured by Billings, as there are four instead of three pairs of spines, the inner short ones being left off from Billings' figure, although their presence on the specimen is indicated by the breaks in the smooth curve of the outline of the region between the inner pair of spines there shown.

Horizon and locality.—This is a rather common species in the pebbles of the conglomerate at Lévis, but has not yet been found elsewhere.

Hungaia minuta Raymond

Pl. 14, fig. 1.

Hungaia minuta RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 442, Pl. 14, fig. 1.

Description.—Pygidium small, short, depressed, except on the median line. Axial lobe short, convex, standing high above the remainder of the pygidium. It has one prominent and one faintly marked ring, and at the crest of the posterior end, a pair of large, smooth tubercles placed close to each other on either side of the median line. Each pleural lobe consists of four ribs, each ending in a flat spine. A narrow groove extends down the median line of each rib, out on to the spine, and at the line of junction of each adjacent pair of ribs there is a low ridge parallel to the furrows. On the median line of the pygidium there is a strongly marked rib which extends to the apex of the re-entrant angle formed by the inner pair of spines.

Measurements.—The pygidium (holotype) is 2.75 mm. long and 4 mm. wide; the axial lobe is 1.50 mm. long and 1.25 mm. wide at the front.

Comparisons.—This pygidium is like that of *Hungaia magnifica* in having a spinose posterior margin, in having each rib furrowed and bounded by a ridge, and in the presence of a median rib behind the axial lobe. It differs, however, in being shorter, and in having fewer rings, a pair of pustules on the axial lobe, and in the outline of the entire pygidium. It may be, that when better known, the species must be removed from Hungaia, but in the absence of knowledge of the cephalon, it is better not to establish a new genus at present.

The pygidium assigned to *Dikelocephalus corax* by Billings is smaller than that of *Hungaia magnifica*, but has the same sort of axial lobe as that species, and so is rather unlike *Hungaia minuta*.

Horizon and locality.—A single pygidium was found in zone 2 of the Missisquoi at Highgate Falls, Vermont, and is now in the Yale University Museum.

Hungaia ? billingsi Walcott.

Hungaia billingsi WALCOTT (nomen nudum), Smithson. Miscl. Colls., 1913, Vol. 57, No. 12, p. 336.

Hungaia billingsi WALCOTT, Smithson. Miscl. Colls., 1924, Vol. 75, No. 1, p. 37, fig. 7.

While the previous edition of this paper was in press, Dr. Walcott published a figure of a trilobite which is presumably the one to which he applied the manuscript name *Hungaia billingsi* in 1913. No description of the genus or species accompanies the figure, but the statement is made that this species is the type of the genus.

Hungaia billingsi is obviously not congeneric with *Dikelocephalus magnificus,* and thence arises a somewhat puzzling situation. As stated above, Dr. Walcott applied the name Hungaia to a described and recognizable species in 1914, when he assigned *Dikelocephalus magnificus* to that genus. In the situation which existed in the fall of 1922, when I wrote my paper, it was not possible to apply a new generic name to the latter species, because Hungaia was already attached to it. It being the only described species, it became automatically the type. It appears, therefore, that some other generic name must be applied to the group typified by *Hungaia billingsi.*

Subfamily *Illaenurinae* Raymond

The cranidium of *Illaenurus quadratus,* as it was known before 1916, was so much like that of Symphysurus that in previous papers I have referred this genus to the Asaphidae, whereas most other writers have considered it a member of the Illaenidae. Dr. Walcott has now figured some very well-preserved specimens which throw a new light on the subject and show that there is certainly no relationship to Symphysurus or to the Asaphidae. As with other smooth trilobites, the affinities of this animal are not obvious. It is true that it resembles an illaenid, but has one more than the typical number of thoracic segments (10) found in that family. The individual segments are Illaenus-like in their smoothness. One of the more commonly used criteria for distinguishing Asaphidae from Illaenidae is the fact that each pleuron of a thoracic segment of a member of the former family has a diagonal furrow, whereas the pleura of the latter are smooth. The figures published by Dr. Walcott (1916, Pl. 45) are somewhat perplexing, for on that basis fig. 1 belongs to the Illaenidae, and fig. 1b to the Asaphidae. Specimens in the Museum of Comparative Zoology show the pleuron to be almost smooth, and it has the appearance of coming to a spine-like termination, because the anterior corner is turned down in the outer half. There is a suggestion of a furrow which turns back to the posterior outer angle.

Although so illaenid-like, there is one strikingly discordant feature, and that is the position of the eyes. Dorsal furrows are absent from the cephalon, but if the furrows of the thorax be projected on to the head, it will be seen that the palpebral lobes border the dorsal furrows, which is not the case in the Illaenidae. The position of the eyes shows that this is not a primitive, but a specialized trilobite, an indication confirmed by the very wide axial lobe, and unfurrowed cephalon and pygidium. Such a form could not have given rise to species with narrow axial lobes and eyes distant from the glabella. Being a highly specialized form, this trilobite must have occupied a terminal position on some line, and can therefore not be an illaenid. As will be shown in the description of a new species of Illaenurus, I am inclined to think this is one of the lines of dikelocephalid evolution, and I propose a new subfamily which will, at the present time, contain two described genera, Illaenurus and Platycolpus, and one new one.

Description.—The new subfamily may be described as follows: Derived Dikelocephalidae, in which the glabella reaches the anterior border, all dorsal and glabellar furrows are reduced or obsolete, and with a pygidium without rings or ribs, sometimes without differentiated axial lobe. Axial lobe of thorax of medium or great width. Number of thoracic segments in the typical genus, eleven.

Illaenurus quadratus Hall.

Illaenurus quadratus HALL, 16th Ann. Rept. N. Y. State Cab. Nat. Hist., p. 176, Pl. 7, fig. 52-57, 1863; Trans. Albany Institute, Vol. 5, p. 168, Pl. 2, fig. 52-57, 1867.—CHAMBERLIN, Geol. Wisc., Vol. 1, p. 130, fig. 16L-P, 1883.—RAYMOND, Ann. Carnegie Mus., Vol. 7, p. 43, fig. 9, 1910.—WALCOTT, Smithson. Misc. Coll., Vol. 64, p. 406, Pl. 45, figs. 1, 1a-1e, 1916.

One specimen from Vermont appears to belong to this species. The curvature is the same as in individuals from Wisconsin, and much less than in *Illaenurus breviceps.* There are no dorsal furrows and the sides of the cranidium in front of the eyes are nearly parallel; an apparent slight convergence may be due to the state of preservation.

Measurements.—Length of cranidium 16 mm., width at the palpebral lobes about 18 mm.

Horizon and locality.—The single specimen is from zone 3 of the Missisquoi at Highgate Falls, Vermont. In the typical region in Wisconsin and Minnesota it is a rather common fossil in the St. Lawrence formation of the Upper Cambrian.

Illaenurus breviceps Raymond.

Pl. 14, fig. 2.

Illaenurus breviceps RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 445, Pl. 14, fig. 2.

Description.—Cranidium short, abruptly deflected toward the front, so as to suggest that the whole cranidium had approximately the shape of the surface of a quarter of a sphere. The glabella, which is evenly convex, occupies the greater part of the cranidium. It is outlined laterally by parallel shallow dorsal furrows, and in front is separated from a very narrow raised border by a shallow linear depression. There are no traces of glabellar furrows, or of an occipital furrow on the axial lobe. In front of the eyes there are no fixed cheeks, but the lobes behind them extend far outward and turn downward. Each bears a narrow depression, showing that the occipital furrow is not entirely obsolete. The palpebral lobes are large, flat, and situated about their own length in front of the posterior margin.

The pygidium is short, wide, rather strongly convex, the position of the axial lobe indicated only by a slight depression on either side on the anterior margin. The surface is smooth.

Measurements.—A cranidium, the holotype, is 9 mm. long, 12 mm. broad at the palpebral lobes, and about 20 mm. wide at the posterior margin. A smaller cranidium is 5.25 mm. long, 6 mm. wide at the palpebral lobes, and about 8 mm. at the posterior margin.

A pygidium (paratype) is 3.25 mm. long, and 7 mm. wide.

Comparisons.—This species is closely allied to *Illaenurus quadratus* Hall, differing from it in the profile, which is somewhat more curved and in having the glabella definitely although faintly outlined by the dorsal furrows. It is also much like *Platycolpus barabuensis* (Whitfield, 1882, p. 201, Pl. 4, fig. 6) but has a more curved profile and a more nearly rectangular glabella, the dorsal furrows being parallel in *Illaenurus breviceps,* whereas they converge forward in *Platycolpus barabuensis. Illaenurus breviceps* thus forms a connecting link between Illaenurus and Platycolpus and, since *Platycolpus eatoni* Whitfield apparently connects Platycolpus with the Dikelocephalidae, brings Illaenurus into that family as a terminal "smoothed-out" representative.

Horizon and locality.—A rare species in zone 3 of the Missisquoi at Highgate Falls, Vermont. Type in Yale University Museum.

Illaenurus laevis Raymond.

Pl. 14, fig. 4.

Illaenurus laevis RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, Pl. 4, p. 446, Pl. 14, fig. 4.

Description.—Cranidium small, almost hemispherical, with large palpebral lobes. Glabella large, with no furrows other than slight depressions at the posterior margin. At the front it is separated from a wide, striated vertical border by a narrow V-shaped furrow. The palpebral lobes are large, centrally situated. The facial sutures turn slightly inward in front of the eyes and cross the striated border. Behind the eyes their course is outward and backward, leaving small, smooth fixed cheeks. Except for the anterior border, the surface is smooth.

Measurements.—The cranidium (holotype) is 5 mm. long, 6 mm. wide at the palpebral lobes, and about 8 mm. wide on the posterior margin.

Comparisons.—This name is proposed for a small trilobite with a smooth, almost hemispherical head, without dorsal, glabellar or occipital furrows, large eyes, and an anterior, vertical, striated border. This last is almost exactly like that of *Platycolpus capax* and *Platycolpus eatoni,* and furnishes the only clue to the family relationship of the species. The specimen was first identified as a Symphysurus, but it lacks the dorsal furrows and the outward bend of the facial suture in front of eye shown in that genus. Illaenurus may claim the species, for the present, in spite of the peculiar anterior border. A minor difference is that the fixed cheeks are not so extended in this trilobite and lack furrows, thus agreeing with Symphysurus.

Horizon and locality.—A rare species in zone 3 of the Missisquoi at Highgate Falls, Vermont. Type in the Yale University Museum.

Genus **Platycolpus** Raymond.

Platycolpus dubius (Billings).

Bathyurus dubius BILLINGS, Canadian Nat. and Geol., Vol. 5, p. 319, fig. 21, 1860; Pal. Fos. Canada, Vol. 1, p. 410, fig. 390, 1863.

Platycolpus dubius RAYMOND, Bull. Victoria Mem. Museum, Vol. 1, p. 64, 1913.

Two imperfect cranidia of this species in the collection furnish the additional information that when not exfoliated, the surface is rather sparsely covered with small, low, smooth granules or pustules. Each shows faint traces of two pairs of glabellar furrows. It should be noted that when perfect, the palpebral lobes are not so long and narrow as shown by Billings' figure. One specimen has one of these very narrow lobes on one side, and a somewhat wider one on the other. The narrower one is obviously imperfect.

Measurements.—The better-preserved cranidium is 10 mm. long and 10.5 mm. wide at the palpebral lobes; the glabella, excluding the occipital segment, is 8 mm. long, 7.75 mm. wide at the back and 6 mm. wide at the front.

Horizon and locality.—A rare species in zone 3 of the Missisquoi at Highgate Falls, Vermont. The original specimens were from boulders in the limestone conglomerate at Lévis, Province of Quebec.

Genus **Cholopilus** Raymond.

Illaenurinae with large eyes, deeply incised dorsal and nuchal furrows, and small fixed cheeks.

Genotype, *Cholopilus vermontanus* Raymond.

This generic name is proposed for a small trilobite which much resembles Leiostegium, but has large eyes. The general appearance is that of Symphysurus, but the well-developed nuchal furrow and ring, and absence of median pustule exclude it from that genus. It is probably most nearly related to Platycolpus, but has larger eyes, smaller fixed cheeks, and a more nearly square glabella than any species of that genus.

Cholopilus vermontanus Raymond.

Pl. 14, figs. 8, 11, 15.

Cholopilus vermontanus RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 448, Pl. 14, figs. 8, 11, 15.

Description.—Cranidium short, subrectangular, moderately convex. Glabella nearly square, evenly curved, separated from a narrow elevated frontal border by a linear furrow. Dorsal furrows narrow but deep, parallel throughout their entire extent. Nuchal furrow narrow and deep across both glabella and cheeks; nuchal segment narrow and convex, without median pustule or spine. Palpebral lobes large, extending back nearly to the nuchal furrow, and forward more than half-way to the front. The anterior and posterior ends of each lobe are separated from the dorsal furrow by a narrow slightly convex ridge. The fixed cheeks behind the eyes are small and do not extend far laterally. The entire surface of the cranidium is covered with small, low pustules or granules which are only visible under a lens.

A free cheek which very probably belongs to this species has a moderately convex surface, with a narrow elevated border separated from the main portion by a shallow groove. The genal angle is obtusely rounded.

The associated pygidium is evenly convex, the axial lobe about one-third the total width, limited by sharp furrows, and extending nearly to the posterior margin. Three rings are present at the anterior end, sharply defined on the cast, but somewhat more smooth where the test is not removed. The pleural lobes are smooth except for the groove on each limiting the anterior half-segment, and there is no convex or concave border.

Measurements.—A cranidium (holotype) is 3.75 mm. long, 3.00 mm. wide at the palpebral lobes, and 4.50 mm. at the nuchal segment. The glabella is 2.75 mm. long, and 2.50 mm. wide at the back.

Comparisons.—If specimens were found without the palpebral lobes, it would be very difficult to distinguish them from *Leiostegium quadratum* (Billings). The cranidium is a little more convex, and perhaps more nearly square, but except for the size of the eyes, there is little difference between the two trilobites.

Horizon and locality.—A rather rare fossil in the Georgia formation at its contact with the Highgate, 4.5 miles north of Highgate Center, Vermont.

Holotype, No. 1735 in the Museum of Comparative Zoology. A single cranidium was found in the Highgate at Highgate Center, Vermont.

Family PTYCHASPIDAE Raymond

Ptychaspis differs widely from the typical Dikelocephalus, almost the only feature common to the two genera being the presence in both of trans-glabellar furrows. Some species of Saukia, however, so much resemble certain ptychaspids, that it is a question whether the latter group should be considered as a subfamily of the Dikelocephalidae, or as a separate family. In view, however, of the prominence of the glabella, the small eyes, the turned-down brim and the short pygidium of the ptychaspids, it seems probable that they were not derived from Dikelocephalidae, and they may for the present be placed in another family.

Genus **Ptychaspis** Hall.

Ptychaspis HALL, 16th Rept. N. Y. State Cab. Nat. Hist., p. 170, 1863.

Hall proposed this genus for two species of Upper Cambrian trilobites, *Dikelocephalus miniscaensis* Owen and *Dikelocephalus granulosus* Owen. Neither was designated as the genotype, neither species has since been removed from the genus, nor has either been by anyone designated, so far as I can find, as the type. The two species differ considerably but not sufficiently to require a generic separation at the present time.

The glabella of *Ptychaspis miniscaensis* tapers forward, has a furrow and convex border in front of it, and the small eyes are but slightly in advance of the middle. *Ptychaspis granulosa* on the other hand has a cylindrical glabella which is crossed by two deep furrows and the eyes are opposite the middle of the frontal lobe of the glabella. The glabella is, moreover, so long that it overhangs the anterior border.

Hall must have had some reason for placing *Ptychaspis miniscaensis* ahead of *Ptychaspis granulosa* in the descriptions but it is obvious that he had the latter species chiefly in mind when in the generic description he says, "Glabella *cylindrical, convex,* deeply lobed or transversely furrowed, *very prominent in front. Eyes anterior to the middle.*" The portions italicized do not apply strictly to *Ptychaspis miniscaensis.* I propose, therefore, to select *Ptychaspis granulosa* Hall as the genotype of Ptychaspis. The

Ptychaspis granulosa Hall is not, however, the *Dikelocephalus granulosus* of Owen, but an entirely distinct species, to which Whitfield gave the specific name of *striata*. *Ptychaspis striata* Whitfield is, therefore, the name of the genotype.

Ptychaspis striata Whitfield.

Ptychaspis granulosa HALL, 16th Rept. N. Y. State Cab. Nat. Hist., p. 173, Pl. 6, figs. 33, 34, 35, 37, 40, and perhaps 36 and 39, 1863.

Ptychaspis striata WHITFIELD, Ann. Rept. Geol. Surv. Wisconsin for 1877, p. 55, 1878; *ibidem*, Rept. for 1879, p. 51; Geol. Wisconsin, Vol. 4, p. 186, 1882.

Whitfield never gave any detailed description of his species, but merely applied the name to those specimens which Hall had identified as Owen's *Dikelocephalus granulosus*. Owen's original description of the latter species was exceedingly brief, and his figures very poor. The identification rests almost wholly upon the pustulose nature of the ornamentation. It is quite obvious that the specimen shown by Hall as figure 33 on Plate 6 does not have a pustulose but a strongly striated surface. That shown in figure 34 is not ornamented at all but Hall explained that this was the cast of an interior whereas the other was a mold of the exterior of a cranidium. In general appearance the two are certainly much alike. It still remains a question, however, whether all of Hall's specimens belong to one species, and it would seem best to designate one of them, that represented as figure 33 on Plate 6, as the type of *Ptychaspis striata*.

So far as I can determine, from what appear to be fairly typical specimens in the Museum of Comparative Zoology, the eyes are much farther forward in *Ptychaspis striata* than in either *Ptychaspis granulosa* (Owen) or *Ptychaspis miniscaensis* (Owen).

Ptychaspis affinis Raymond.

Pl. 14, fig. 6.

Ptychaspis affinis RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 450, Pl. 14, fig. 6.

Description.—Cranidium very similar to that of *Ptychaspis granulosa* (Owen) as exhibited by specimens from the Franconia in St. Croix Co., Wisconsin. Glabella oblong, prominent, but not elevated greatly above the fixed cheeks. The first glabellar furrows are indentations at the sides at about the middle of the length. They are short, turn slightly backward, and their inner ends do not meet. The second pair unite to produce one deep furrow which extends across the posterior portion of the glabella close to the occipital furrow and nearly parallel to it. The circum-glabellar furrow is narrow but deep, the fixed cheeks rising as an engirdling ridge, which, however, is turned downward at the front. The palpebral lobes are small, situated opposite the first glabellar furrows, and at about the middle of the cranidium. The test is mostly chipped off the type, but the glabella appears to have been granulose.

Measurements.—Length of cranidium of holotype 8 mm., width at palpebral lobes 9 mm., at posterior margin 14 mm.; length of glabella and neck-ring 6.5 mm.; width of glabella at back 5 mm., at front 4.25 mm.

Comparisons.—This species is much like *Ptychaspis granulosa* (Owen) in general configuration, but although the surface may have been somewhat granulose, it probably was not markedly so. The anterior glabellar furrows are much shorter than those of *Ptychaspis granulosa*, and the posterior ones deeper and have a course more nearly straight across the glabella. The eyes are farther back than those of *Ptychaspis striata* Whitfield, and there is no indication of the striated surface. *Ptychaspis minuta* Whitfield does not show continuous posterior glabellar furrows.

Horizon and locality.—A rare fossil in zone 3 of the Missisquoi at Highgate Falls, Vermont. Type in the Yale University Museum.

Genus **Keithia** Raymond.

One of the common fossils at Highgate Falls is a small trilobite which has a marked resemblance to Ptychaspis, but which is characterized by a large glabella which expands forward, has three instead of two pairs of glabellar furrows, no pair of which entirely cross the axial lobe. The posterior furrows almost unite, however, and the cheeks rise from the circum-glabellar furrow and then slope abruptly downward at the sides as in Ptychaspis, to which the genus is probably most closely allied.

Genotype, *Keithia schucherti* Raymond. Named for Arthur Keith who discovered the locality at Highgate Falls, as well as many others, in the course of his fruitful survey of northwestern Vermont.

Keithia schucherti Raymond.

Pl. 14, figs. 5, 9.

Keithia schucherti RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 452, Pl. 14, figs. 5, 9.

Description.—Cranidium narrow, about two-thirds as long as wide, the prominent glabella extending quite to the front, and overhanging the narrow convex border. The glabella is large, convex, expands forward, becoming increasingly convex to the middle of the frontal lobe, which has a very steep convex anterior slope. Three pairs of glabellar furrows are present. The first are narrow and shallow and merely indent the sides of the anterior portion of the glabella. The inner ends turn slightly forward. The second pair are wider and deeper, extending farther up the sides of the glabella, and their inner ends turn slightly backward

The last two furrows are the deepest and are long enough so that on some specimens their inner ends are almost united. They turn backward and then pursue a course parallel to the occipital furrow, as in Ptychaspis, but fail to produce a continuous furrow across the lobe. The neck-ring is narrow, with a very small median pustule.

The circum-glabellar furrow is narrow and the fixed cheeks moderately convex, the outer portions sloping downward. The occipital lobes are narrow just behind the middle of the cranidium, and connected with the frontal lobe by eye-lines. The course of the facial suture is apparently the same as that of Ptychaspis.

Measurements.—The holotype (a cranidium) is 7 mm. long, 11 mm. wide at the posterior margin, and 10 mm. wide at the palpebral lobes. Most of the specimens are of about this size: a few are smaller.

Comparisons.—This species is very similar to *Arionellus subclavatus* Billings, but the latter has an oval glabella and very oblique posterior glabellar furrows. *Arionellus subclavatus* is certainly to be referred to the genus Keithia and known as *Keithia subclavata* (Billings). *Ptychaspis minuta* Whitfield has incomplete posterior glabellar furrows but the glabella narrows instead of expanding forward, and the species is probably best left in Ptychaspis.

Horizon and locality.—This is perhaps the most common trilobite in zone 3 of the Missisquoi at Highgate Falls, Vermont. I have not found it in collections from the lower horizons. Type in Yale University Museum.

OPISTHOPARIA OF UNCERTAIN SYSTEMATIC POSITION.

Genus **Ambonolium** Raymond.

This name is proposed for a trilobite of quite undetermined relationship. It is known from six cranidia and eight pygidia, which are placed together because of their association in the fragments of limestone. Since there is no proof that they belong together, the cranidium is made the holotype of the species and the genus also is based upon it.

Cranidium dominated by the large glabella which spreads out behind the eyes. Glabellar and dorsal furrows absent, eyes large, in front of the middle. Anterior brim extremely narrow.

Genotype, *Ambonolium lioderma* Raymond.

Ambonolium lioderma Raymond.

Pl. 14, figs. 10, 14.

Ambonolium lioderma RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 453, Pl. 14, figs. 10, 14.

Description.—Cranidium composed chiefly of the glabella, which has in front of it a very short, upturned, lip-like border, and beside it, back of the palpebral lobes, small fixed cheeks. The eyes are large, in front of the middle, and the unfurrowed palpebral lobes form flat projections from the glabella. There are no dorsal or glabellar furrows, and the occipital furrow on the axial lobe is present only across the median portion, where it is narrow and faint. A shallow occipital furrow crosses the fixed cheeks.

The glabella is evenly convex and expands back of the eyes, so that its outer margin at the widest part is on a line with the outer edge of the palpebral lobe. At the posterior lateral angles there is a suggestion of a pair of basal lobes. Surface of cranidium smooth.

The pygidium, which in one specimen is directly associated with this cranidium, is wider than long, without concave margin, the pleural lobes ribless except for the anterior half ridge, the axial lobe long, extending quite to the posterior margin, narrow, with indistinct rings the entire length.

Measurements.—Length of cranidium 9 mm.; width at palpebral lobes 9 mm.; width of glabella back of eyes 9 mm. Pygidium, 7 mm. long, 11 mm. wide; axial lobe 3 mm. wide at the front.

Comparisons.—The cranidium of this species is more nearly comparable to that of *Lloydia bituberculata* than to any other trilobite I know. Both have large tapering glabellae, narrow anterior rim and a flattening of the sides of the posterior portion of the glabella. *Lloydia bituberculata,* however, has wider cheeks in front of the eyes, and very definite dorsal furrows. It may be that better specimens will show that *Bathyurus bituberculatus* should be transferred from Lloydia to Ambonolium.

Horizon and locality.—This species, as represented by pygidia, is rather common in zone 3 of the Missisquoi at Highgate Falls, Vermont, and two specimens have been found in zone 2. Types in the Yale University Museum.

Genus **Gignopeltis** Raymond.

Billings described, under the generic designation of Dolichometopus, three species which are known from pygidia only. It has not yet been possible to connect any cephalon or cranidium with any of these pygidia but since they are rather common fossils and obviously do not belong to Dolichometopus, it becomes necessary, if only as a matter of convenience, to assign them a generic name.

The pygidia are moderately convex, with a broad axial lobe which is not much elevated above the general surface, have ill-defined or no rings and ribs, and lack a concave border.

Dolichometopus ? *rarus* Billings may be selected as genotype.

Gignopeltis rara (Billings).

Dolichometopus ? rarus BILLINGS, Pal. Foss. Canada, Vol. 1, p. 352, fig. 338, 1865.

A pygidium from the Georgia formation appears to belong to this species. It is two-thirds as long as broad, the axial lobe extends five-eighths the length, and occupies about one-third the breadth. It has four ill-defined rings, and there are three pairs of flat ribs, scarcely separated by narrow, shallow furrows. The groove behind the axial lobe is nearly straight.

This pygidium differs somewhat from *Gignopeltis rara* in having an extra pair of ribs, but they are so ill-defined as almost to escape notice. *Gignopeltis convexa* (Billings, 1865, p. 269, fig. 253) is closely allied, but appears to have furrowed ribs, and only one ring on the axial lobe, whereas *Gignopeltis gibberula* (Billings, 1865, p. 269, fig. 254) has only one pair of furrows and a much shorter axial lobe. *Gignopeltis truncata* (Whitfield, 1891, p. 37, p. 2, fig. 6-8) has the axial lobe exceedingly like that of the present species, except that it lacks rings.

Horizon and locality.—From the Georgia formation, 4.5 miles north of Highgate Center, Vermont. All of the known species of this genus are from the Beekmantown.

Genus **Leiostegium** Raymond.

Leiostegium puteatum Raymond.

Pl. 14, figs. 12, 13, 16, 19.

Leiostegium puteatum RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 455, Pl. 14, figs. 12, 13, 16, 19.

Description.—Cranidium gently convex, somewhat quadrangular in outline. Glabella elongate, nearly rectangular but gently rounded at the front. Dorsal furrows narrow, not deep, ending anteriorly in a pair of pits. In front of the glabella is a narrow furrow bordering an equally narrow upturned and striated rim. The fixed cheeks rise as a sort of roll from the dorsal furrows to about the same height as the top of the glabella. Palpebral lobes large, a little back of the middle, and well out from the dorsal furrows. Occipital furrow narrow and deeply impressed.

Measurements.—The holotype, a cranidium, is 13.5 mm. long, and about 17 mm. wide at the palpebral lobes. A smaller cranidium is 9.5 mm. long, and there is a very poorly preserved one which is about 27 mm. long.

Comparisons.—This species differs from *Leiostegium quadratum* in having a longer and narrower glabella and particularly in possessing a pair of deep pits at the anterior ends of the dorsal furrows. The pits, together with the shape of the glabella and brim, cause this cranidium so greatly to resemble that of Olenoides as to lead to danger of misidentifications. In the present species, however, eye-lines and a nuchal spine are absent.

Another, apparently closely allied trilobite is *Barrandia ? mccoyi* Walcott (1884, p. 96, Pl. 12, fig. 5) a species which can probably also be transferred to Leiostegium. Pits are present at the ends of the dorsal furrows of this species, and it appears to differ from *Leiostegium puteatum* only in that the glabella expands forward.

Horizon and locality.—Several cranidia of this species were found in the lower part of the Highgate limestone at Highgate Center, Vermont, and one large but imperfect cranidium at another locality in the Highgate limestone two miles north of Highgate Center. *Leiostegium quadratum* occurs in the pebbles of the conglomerates at Lévis and in the Beekmantown at Philipsburg, Quebec. *Leiostegium mccoyi* (Walcott) was found in the lower part of the Pogonip limestone (a zone about equivalent to the base of the Beekmantown) in Nevada.

Leiostegium cingulosum Raymond.

Pl. 14, figs. 18, 21.

Leiostegium cingulosum RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 456, Pl. 14, figs. 18, 21.

Description.—The cranidium of this species is very like that of *Leiostegium puteatum*, but the anterior end of the glabella has a more rounded outline, and there are two pits on either side, one at the junction of each dorsal with the intra-marginal furrow, and another just behind it in the dorsal furrow.

Associated pygidium semicircular, strongly convex, without concave border. Axial lobe strongly convex, less than one-third the total width, reaching nearly to the posterior margin. It bears five rings, the last two of which are indistinct. Except for the anterior half-rib, which is distinctly marked, the pleural lobes are ribless, and slope steeply. The specimen is exfoliated, showing a narrow doublure, which leaves a narrow flat margin on the cast.

Measurements.—Length of cranidium 13 mm.; width of glabella at front 8.5 mm., at back about 8.5 mm. (damaged). Length of pygidium 10.5 mm., width 20 mm.; length of axial lobe 8.5 mm., width at front 5 mm.

Comparisons.—The glabella is much less quadrate than that of *Leiostegium quadratum* (Billings), and the rim is flatter. The pygidium is relatively wider and its axial lobe is more prominent and more distinctly ringed.

Horizon and locality.—Found in the lower part of the Highgate formation 1.5 miles north of Highgate Center, Vermont. The pygidium is designated as the holotype and the cranidium as the paratype.

Order PROPARIA Beecher.

Family CHEIRURIDAE Salter.

Subfamily *Cheirurinae* Raymond.

Genus **Pilekia** Barton.

This genus has for its type *Cheirurus apollo* Billings, and includes species with a cephalon like Cyrtometopus and a somewhat elongate, spinose pygidium which suggests Pliomera, but is different in that each rib has a median longitudinal furrow, instead of a rib. *Pilekia apollo* has a somewhat rapidly tapering glabella, but *Pilekia foveolata* (Angelin) with the same sort of pygidium, has a long, narrow glabella.

Pilekia extenuata Raymond.

Pl. 14, figs. 17, 20.

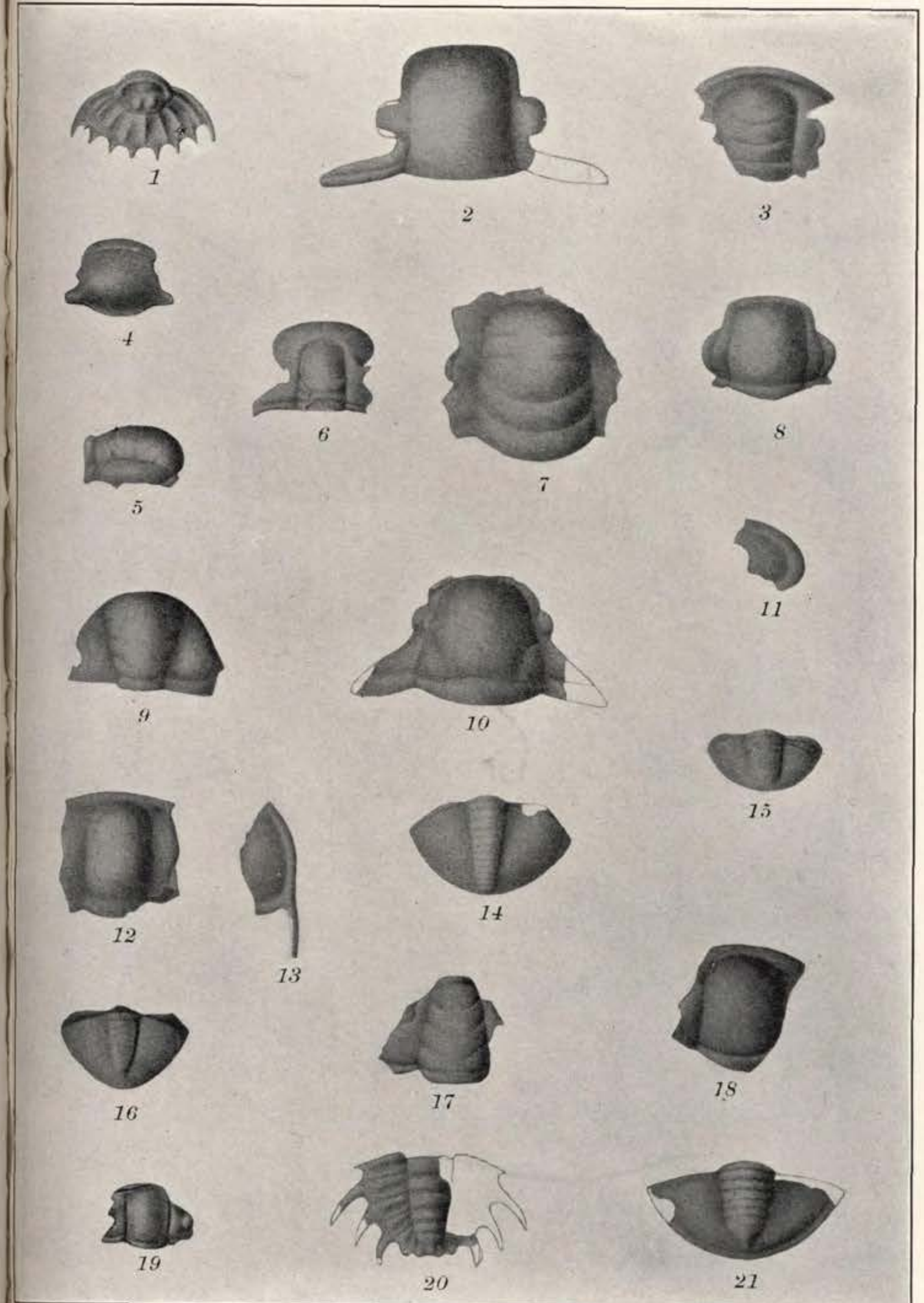
Pilekia extenuata RAYMOND, Proc. Boston Soc. Nat. Hist., 1924, Vol. 37, No. 4, p. 457, Pl. 14, figs. 17, 20.

Description.—All of the specimens—five cranidia and one pygidium—are either distorted or imperfect, so that the exact shape of the cephalon cannot be learned. The glabella is elongate, reaching nearly to the anterior margin, bounded by a very narrow furrow and lip-like rim. It is nearly parallel-sided, gently convex, rounded in front when not distorted. There are three pairs of diagonally directed glabellar furrows, the last the longest and most deeply impressed. The first pair are close to the anterior end, so that the frontal lobe is short. Fixed cheeks wide back of the eyes, with genal spines extended straight backward, but narrow in front of them. The palpebral lobes are small, situated far forward and rather close to the glabella. They are connected by a well-defined ocular ridge with the middle of the frontal lobe. Occipital furrow narrow but deep; nuchal segment narrow. The entire surface is covered with small granules.

Pygidium moderately convex, with four pairs of long marginal spines and vestiges of two more pairs in the middle at the posterior end. Axial lobe long and prominent, with five strongly defined rings and triangular terminal boss. Pleural lobes composed of furrowed segments, four pairs of which end in curved spines. The furrows are wide and medially placed, and there are narrower furrows between adjacent segments, so that each pleural lobe appears to be covered with narrow radiating ridges. Surface granulose.

Measurements.—Length of an undistorted cranidium (holotype) 11 mm.; width at base of glabella 7 mm., at outer ends of anterior glabellar furrows 6 mm. A large cranidium is about 18 mm. long. Pygidium 7 mm. long, and about 12 mm. wide at the front, excluding spines.

Fig.	1.	*Hungaia minuta* Raymond. × 4 2/3.
Fig.	2.	*Illaenurus breviceps* Raymond. × 2.
Fig.	3.	*Richardsonella germana* Raymond. ×1 1/3.
Fig.	4.	*Illaenurus laevis* Raymond. × 2.
Figs.	5, 9.	*Keithia schucherti* Raymond. × 2.
Fig.	6.	*Ptychaspis affinis* Raymond. × 1 1/3.
Fig.	7.	*Saukia dunbari* Raymond. × 2.
Fig.	8.	*Cholopilus vermontanus* Raymond. × 4.
Figs.	10, 14.	*Ambonolium lioderma* Raymond. × 2.
Fig.	11.	*Cholopilus vermontanus* Raymond. A free cheek. × 1 1/3.
Fig.	12.	*Leiostegium puteatum* Raymond. × 1 1/3.
Figs.	13, 16.	*Leiostegium puteatum* Raymond. A free cheek and a pygidium. × 1.
Fig.	15.	*Cholopilus vermontanus* Raymond. × 2 1/3.
Fig.	17.	*Pilekia extenuata* Raymond. × 1 1/3.
Figs.	18, 21.	*Leiostegium cingulosum* Raymond. × 1 1/3.
Fig.	19.	*Leiostegium puteatum* Raymond. A cranidium. × 2/3.
Fig.	20.	*Pilekia extenuata* Raymond. × 2.



Comparisons.—The best known American species of this genus is *Pilekia apollo* (Billings), a trilobite which has been found in the conglomerates at Lévis only. It differs very much from that species, having a longer and narrower glabella which does not taper rapidly forward. The pygidia are of the same type, but that of *Pilekia apollo* has very narrow pleural furrows instead of wide ones, and shows only traces of spines back of the axial lobe.

Pilekia foveolata (Angelin) (1854, Pl. 39, fig. 8; Broegger, 1882, Pl. 2, fig. 5) is apparently a still more closely allied form, but has deeper glabellar furrows, and, if the figure is correct, wider fixed cheeks in front of the eyes.

Pilekia speciosa (Dalman) and *Pilekia primigena* (Angelin) (Moberg and Segerberg, 1906, Pl. 7, fig. 12-16) have cranidia very like that of the species here described, but the pygidium of the first appears to lack pleural furrows, and that of the second has five pairs of long marginal spines. All of these species belong to the Euloma-Niobe fauna, and suggest that *Pilekia extenuata* may be of about the same age.

Horizon and locality.—Five of the specimens are from the Highgate limestone at a locality 2 miles north of Highgate Center, Vermont. One imperfect cranidium is from the same limestone at another locality 1.5 miles north of Highgate Center.

Pilekia eryx (Billings).

Cheirurus eryx BILLINGS, Canadian Nat. and Geol., Vol. 5, p. 322, fig. 30, 1860; Geol. Canada, p. 239, fig. 276, 1863; Pal. Foss. Canada, Vol. 1, p. 413, fig. 399, 1865.

A single cranidium from the base of the Georgia formation 4.5 miles north of Highgate Center, Vermont, is referred to this species. It retains the glabella, part of one, and all of the other fixed cheek. The glabella is compressed, but tapers somewhat forward, has a very narrow rim separated from the glabella by a linear furrow, and three pairs of deeply incised glabellar furrows. The eye is situated opposite the middle of the glabella, and is connected with it by an ocular ridge. The genal spines are short, but longer than shown in Billings' figure.

Although the eye is rather farther back than in most species of the genus, excepting, however, *Pilekia primigena* (Angelin), there is little doubt but that it is a close relative of the cheirurids which are found in the Ceratopyge zone of Sweden.

SUMMARY AND CORRELATION OF FORMATIONS.

MISSISQUOI FORMATION.

The Missisquoi formation as exposed in the gorge at Highgate Falls, Vermont, consists of thinly bedded limestone, and glomeratic strata, made up of angular and rounded fragments of limestone in a calcareous matrix. Fossils have been collected at four horizons distributed through an interval of about 100 feet. Those from the uppermost zone, above the thickest conglomerate, are so few that they are not listed here, and those of the second and third zone, which are from layers separated by only a few feet of strata, are listed together. The strata of the "lowest zone" are some seventy feet below those of the "main zone."

Lowest Zone.

Pseudosalteria laevis Raymond	*Acheilus macrops* Raymond
Asaphiscus inornatus Raymond	*Apatokephaloides clivosus* Raymond
Plethopeltis lata Raymond	*Dikelocephalus insolitus* Raymond
Richardsonella laeviuscula Raymond	

Main Zone.

Agnostus innocens Clark	*Plethopeltis lata* Raymond
Agnostus trisectus Salter	*Plethopeltis convergens* Raymond
Agnostus insuetus Raymond	*Stenopilus pronus* Raymond
Pseudagnostus extumidus Raymond	*Stenopilus brevis* Raymond
Peronopsis planulata Raymond	*Corynexochus juvenis* Raymond
Phalacroma parilis (Hall)	*Acheilus macrops* Raymond
Phalacroma cyclostigma Raymond	*Acheilus spicatus* Raymond
Idiomesus tantillus Raymond	*Apatokephaloides clivosus* Raymond
Phoreotropis puteatus Raymond	*Apatokephaloides inflatus* Raymond
Phoreotropis transversus Raymond	*Saukia lodensis* (Whitfield)
Zacompsus clarki Raymond	*Saukia stosei* (Walcott)
Onchonotus nasutus (Walcott)	*Saukia dunbari* Raymond
Phylacterus saylesi Raymond	*Richardsonella germana* Raymond
Phylacterus fraternus Raymond	*Hungaia minuta* Raymond
Blountia imitator Raymond	*Illaenurus quadratus* Hall
Maryvillia triangularis Raymond	*Illaenurus breviceps* Raymond
Lloydia seelyi (Walcott)	*Illaenurus laevis* Raymond
Plethopeltis armata (Billings)	*Platycolpus dubius* (Billings)
Plethopeltis laevis Raymond	*Ptychaspis affinis* Raymond
Plethopeltis angusta Raymond	*Keithia schucherti* Raymond
Ambonolium lioderma Raymond	

Three of the seven species identified in the lower zone are found also in the upper one. Asaphiscus is normally a Middle Cambrian genus belonging to the Pacific province, but as stated in the description of *Asaphiscus inornatus,* there is a possibility that better material may show this generic reference inaccurate. In other respects the fauna of the lower zone is of the same type as that found in the higher strata.

The fauna as a whole, although consisting largely of previously unknown species, is distinctly of the facies of the Upper Cambrian of interior North America, as indicated by the presence of Saukia, Dikelocephalus and Illaenurus, and the absence of any European animals except *Agnostus trisectus.*

If comparison be made with the faunas of the St. Croixan of the upper Mississippi valley, one finds but few species common to the two regions, but such evidence as there is points to correlation with the upper part of the Upper Cambrian, that is, with the

Franconia and St. Lawrence formations. The St. Lawrence formation contains the great development of species of Saukia and Dikelocephalus, and two of the species found at Highgate Falls, *Saukia lodensis* (Whitfield) and *Illaenurus quadratus* Hall, are characteristic of the St. Lawrence. The Franconia appears to be the principal horizon for Ptychaspis, and one of our agnostids, *Phalacroma parilis* (Hill), was described originally from that horizon.

There is also considerable similarity between the faunas of the Missisquoi and the Saratogan formations of New York and New Jersey. Noteworthy is the abundance of Plethopeltis, and the presence of Saukia, Richardsonella and Ptychaspis. *Lloydia seelyi* occurs in the Potsdam of New York as well as in the Missisquoi. The fauna of the Missisquoi is so much richer and more varied than that of the Saratogan as to suggest that the latter was derived from the former, but whether contemporaneously or after a lapse of time remains to be proved. The presence of Blountia and Maryvillia, two genera of the Upper Cambrian of eastern Tennessee, and of *Saukia stosei,* a trilobite of the Conococheague of Pennsylvania, shows connections along the Appalachians south of New Jersey.

It is not very surprising to find in the Missisquoi a number of species identical with or closely allied to those found in the boulders in the conglomerates at Lévis, but it is a satisfaction to find these forms in place. *Agnostus innocens* Clark, *Onchonotus nasutus* (Walcott), *Plethopeltis armata* (Billings), *Plethopeltis angusta* Raymond, and *Platycolpus dubius* (Billings) are the species so far found at both localities. In addition, there are closely related species of Acheilus, Richardsonella, Hungaia, and Keithia.

The single European species, *Agnostus trisectus* Salter, is found in the upper part of the Upper Cambrian (Peltura zone) in Europe and on Cape Breton in America.

The weight of evidence, at the present time, seems to indicate that the thinly bedded, fossiliferous part of the Missisquoi at Highgate Falls is to be referred to the upper part of the Upper Cambrian. There is, however, so much that is novel in the fauna that fuller knowledge may make a revision of this opinion necessary.

HIGHGATE FORMATION.

The Highgate formation consists largely of shale, but in the lower portion layers of limestone an inch or two in thickness are interstratified with partings of shale. All of the known outcrops of this formation are in a region which is considerably compressed, so that a schistosity has been produced nearly at right angles to the bedding, making it exceedingly difficult to break the rock in such a way as to reveal the fossils. Curiously, such fossils as can be obtained show comparatively little distortion. The most prolific locality so far found is a small outcrop at the entrance of a pasture at the western edge of the village of Highgate Center. Eight species of trilobites have been collected there. A list from all localities, so far as the species are now identified, is as follows:

Agnostus, sp. ind.	*Leiostegium cingulosum* Raymond
Hypagnostus, sp. ind.	*Maryvillia triangularis* Raymond
Leptopilus declivis Raymond	*Lloydia seelyi* (Walcott)
Cholopilus vermontanus Raymond	*Lloydia saffordi* (Billings)
Leiostegium puteatum Raymond	*Hemigyraspis*, sp. ind.
Pilekia extenuata Raymond	

This fauna contains only two species found in the Missisquoi, namely, *Lloydia seelyi* and *Maryvillia triangularis*. On the other hand, the most common species, *Leiostegium puteatum* and *Pilekia extenuata*, belong to genera which are characteristic of the Lower Ordovician, as does Hemigyraspis. The specimens of *Lloydia saffordi* are large and closely comparable to those found in the Beekmantown at Philipsburg, Quebec, and *Cholopilus vermontanus* as well as *Lloydia saffordi* occur in the next-higher formation, the Georgia.

So far as can be judged from the trilobites as known at the present writing, the Highgate would be termed Ordovician rather than Cambrian but would be placed about on the border between the two. Pilekia and Hemigyraspis are the only genera which belong to the Ceratopyge fauna.

GEORGIA FORMATION.

The Georgia formation is best exposed directly north of Highgate Center and within a mile or two of the Canadian border. Like the Highgate it consists chiefly of shale, but has some limestone in the lower portion. At one locality fossils are numerous, but badly preserved; at another, where the Georgia and Highgate are in contact, the fossils are well preserved, but the quantity of material to be had is very limited.

The following species have so far been determined, all from the lower part of the formation:

Agnostid, gen. et sp. ind.	*Lloydia saffordi* (Billings)
Cholopilus vermontanus Raymond	*Lloydia*, sp. ind.
Petigurus cybele (Billings)	*Bellefontia obtecta* Raymond
Gignopeltis rara (Billings)	*Bellefontia*, sp. ind.
Hystricurus mammatus Raymond	*Pilekia eryx* (Billings)
Pliomerops, sp. ind.	

The presence of *Petigurus cybele*, *Gignopeltis rara*, *Lloydia saffordi*, and *Lloydia*, sp. ind., which is an undescribed species known at Philipsburg, Quebec, indicates that this is a Beekmantown fauna, but so little is known of the range of trilobites in the Beekmantown that it would not be safe to make a definite correlation with any particular division. The genera Bellefontia and Pilekia would indicate a horizon very low in the Lower Ordovician; there is nothing to indicate a correlation with any member near the top of the Beekmantown, nothing, at least, higher than the Fort Cassin.

THE "OZARKIAN" QUESTION.

I have left to the last a consideration of whether any of the faunas of this region may be considered as Ozarkian. The moment is very inopportune for such a discussion, since it is understood that the first papers descriptive of Ozarkian fossils will appear in 1924, and this is written in November, 1923. Dr. Walcott (1923, p. 457-476) has recently summarized the stratigraphy of the Ozarkian, presenting the views of Dr. Ulrich and himself up to the end of 1922. In it he has given lists of fossils, many of them, however, merely manuscript names, which do not allow fruitful comparisons.

The Hoyt limestone (Saratogan) is referred to the Sarceen, or lower division of the Ozarkian. I have pointed out above the similarities of the faunas of the Missisquoi and the Hoyt. No other eastern formation now referred to the Ozarkian is well enough known to invite comparison.

The St. Charles formation of Utah and Idaho contains, according to Walcott, a large fauna, and the succession appears to be somewhat comparable to that in Vermont. The trilobites in the highest zone are recorded as *Hystricurus*, sp. ind., *Blountia*, sp. ind., *Asaphus* ? sp. ind., and *Ptychostegium idahoensis*. From the fact that *Barrandia ? mccoyi* Walcott is in another list called Ptychostegium, I infer that name applies to trilobites much like those called Leiostegium in this paper. This little fauna, therefore, recalls that of the Georgia.

About 1,200 feet lower down, near the base of the St. Charles, the fauna consists chiefly of trilobites, but unfortunately, largely of undescribed genera and species. There are, however, two species of Saukia, suggesting the presence of a fauna somewhat like the Missisquoi. Walcott states that this fauna "has a very strong Upper Cambrian character."

The Mons of Alberta represents the Ozarkian in that region, according to Walcott. Eighteen feet below the summit two species of Ptychostegium were found in a fauna composed mostly of Mollusca. Sixty feet lower, Megalaspis? and Maryvillia were encountered, and at the base of the section, about 1,400 feet lower, a small fauna with Ptychaspis, Saukia, and Blountia.

Apparently, in these regions the succession is broadly the same as that observed in northwestern Vermont, and it may be that the Missisquoi, Highgate and Georgia would be placed by some in the Ozarkian. As has long been known, there is a rather gradual change from the Upper Cambrian through the Beekmantown, and I am in sympathy with the idea of connecting the two in one system. In this particular region, however, there is so marked a change between the faunas of the Missisquoi and the Highgate that there need be no fear of confusing them, and it appears to be more than usually easy to draw a boundary between the Cambrian and the Ordovician.

LITERATURE.

Angelin, N. P. 1854. Palaeontologia Scandinavica. Pars 1. Crustacea formationis transitionis. 4to, Stockholm.

Berkey, C. P. 1898. Geology of the St. Croix Dalles. III. Part III. Paleontology. Am. Geologist, Vol. 21, p. 270-294, Pl. 17-21.

Billings, E. 1865. Palaeozoic fossils [of Canada]. Vol. I. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. 8vo, Montreal, Geol. Surv. Canada, 426 pp., illustr.

Broegger, W. C. 1882. Die silurischen Etagen 2 und 3 im Kristianiagebiet und auf Eker. Universitätsprogram für 2. Sem., Christiania, viii + 376 pp., Pl. 1-12, map.

Cleland, H. F. 1900. The Calciferous of the Mohawk valley. Bulls. Am. Paleont., Vol. 3, No. 13, p. 1-26, Pl. 13-17.

Hall, James. 1863. Preliminary notice of the fauna of the Potsdam sandstone; with remarks upon the previously known species of fossils, and descriptions of some new ones, from the sandstone of the upper Mississippi valley. 16th Rept. N. Y. State Cab. Nat. Hist., p. 119-226, Pl. 6-11.

Keith, A. 1923. Cambrian succession of northwestern Vermont. Am. Journ. Sci., Ser. 5, Vol. 5, p. 97-139.

Lake, P. 1906. British Cambrian trilobites. Part 1. Palaeontogr. Soc., London.

Matthew, G. F. 1903. Report on the Cambrian rocks of Cape Breton. Geol. Surv. Canada, 246 pp., 18 pls.

———. 1905. Cambrian rocks and fossils of Cape Breton. Ann. Rept. Geol. Surv. Canada, New Ser., Vol. 14, p. 223A-232A.

Moberg, J. C., and Segerberg, C. O. 1906. Bidrag till kännedomen om Ceratopygeregionen med särskild hänsyn till dess utveckling i Fogelsängstrakten. Lunds Univ. Arsskr., New Ser., Pt. 2, Vol. 2, No. 7, 116 pp., 7 pls.

Owen, D. D. 1852. Report of a geological survey of Wisconsin, Iowa, and Minnesota; and incidentally of a portion of Nebraska Territory. Made under instructions from the United States Treasury Department. 4to, Philadelphia, p. i-xxxviii, 39-638, Pl. 1-15, maps, frontispiece (U. S. Geol. Surv.).

Raymond, P. E. 1910. Notes on Ordovician trilobites. II. Asaphidae from the Beekmantown. Ann. Carnegie Mus., Vol. 7, p. 35-45, Pl. 14, text-fig. 1-9.

Walcott, C. D. 1884. Paleontology of the Eureka district. Monogr. U. S. Geol. Surv., Vol. 8, xiii, 298 pp., Pl. 1-24, text. fig. 1-7.

———. 1912. Cambrian geology and paleontology. II. No. 9.—New York Potsdam-Hoyt fauna. Smithson. Misc. Coll., Vol. 57, p. 251-304, Pl. 37-49.

———. 1913. The Cambrian faunas of China. Research in China, Carnegie Inst. Washington, Publ. 54, Vol. 3, p. 1-228, Pl. 1-24.

———. 1914. Cambrian geology and paleontology. II. No. 13.—Dikelocephalus and other genera of the Dikelocephalinae. Smithson. Misc. Coll., Vol. 57, p. 345-411, Pl. 60-70.

———. 1916. Cambrian geology and paleontology. III. No. 5.—Cambrian trilobites. Smithson. Misc. Coll., Vol. 64, p. 303-456, Pl. 45-67.

———. 1923. Cambrian geology and paleontology. IV. No. 8.—Nomenclature of some Post-Cambrian and Cambrian Cordilleran formations (2). Smithson. Misc. Coll., Vol. 67, p. 457-476.

Westergard, A. H. 1909. Studier ofver Dictyograptusskiffern och dess gränslager, med särskild hänsyn till i skane forekommande bildningar. Lunds Univ. Arsskr., New Ser., Pt. 2, Vol. 5, No. 3, 79 pp., 5 pls.

———. 1922. Sveriges Olenidskiffer. Sveriges Geologiska Undersokning, ser. Ca, No. 18, p. 1-205, Pl. 1-16.

Whitfield, R. P. 1882. Palaeontology. In Geology of Wisconsin, Vol. 4, p. 161-363, Pl. 1-26.

———. 1891. Observations on the fauna of the rocks at Fort Cassin, Vermont, with descriptions of a few new species. Bull. Am. Mus. Nat. Hist., Vol. 3, p. 25-39, Pl. 1-3.

Wiman, C. 1902. Ein neuer Trilobit im Dictyonemaschiefer (Palaeontologische Notizen 3-6). Bull. Geol. Inst., Upsala, Vol. 6, p. 77-83.

REPORT

OF THE

STATE GEOLOGIST

ON THE

MINERAL INDUSTRIES AND GEOLOGY

OF

VERMONT

1923-1924

FOURTEENTH OF THIS SERIES

GEORGE H. PERKINS

State Geologist and Professor of Geology
University of Vermont

BURLINGTON, VT.:
FREE PRESS PRINTING CO.
1924.

STAFF OF THE VERMONT GEOLOGICAL SURVEY, 1923-1924.

GEORGE H. PERKINS, *State Geologist, Director.*
Professor of Geology, University of Vermont.
ELBRIDGE C. JACOBS, *Assistant Geologist.*
Professor Mineralogy, University of Vermont.
CHARLES H. RICHARDSON, *Assistant Geologist.*
Professor of Mineralogy, Syracuse University.
CLARENCE E. GORDON, *Assistant Geologist.*
Professor of Geology, Massachusetts Agricultural College.
E. J. FOYLES, *Field Assistant Geologist.*
Am. Museum Natural History, New York City.
Contributing Geologists:
ARTHUR KEITH, U. S. Geological Survey.
PROFESSOR PERCY E. RAYMOND, Harvard University.
PROFESSOR GEORGE D. HUBBARD, Oberlin College.

CONTENTS.

THE GEOLOGY OF SHOREHAM, BRIDPORT AND FORT CASSIN, VERMONT.

Edward J. Foyles

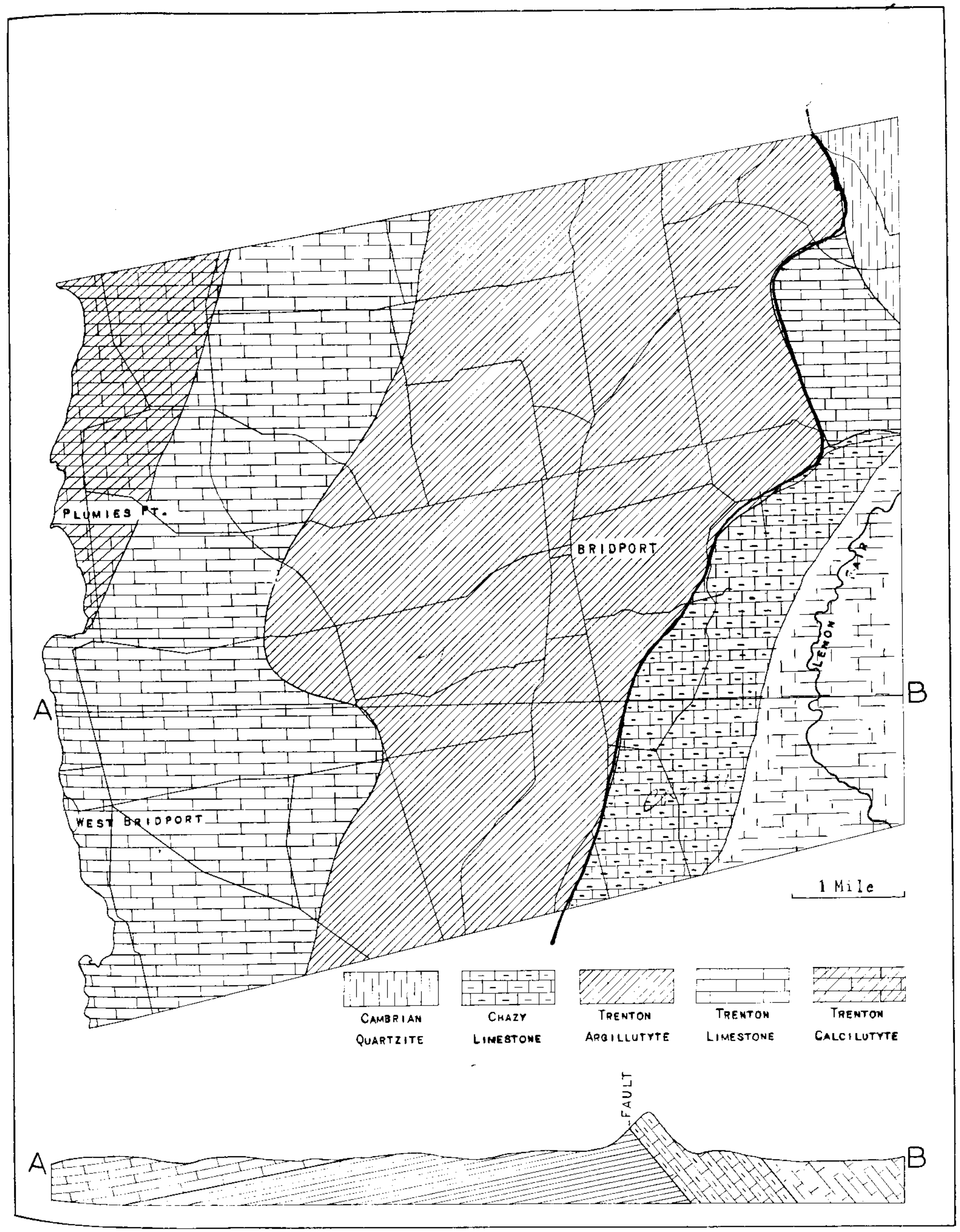
TABLE OF CONTENTS.

INTRODUCTION.

The present paper is the second of a series in which I am attempting to show the true ages of those rocks in the Champlain valley of Vermont which have been called Beekmantown [1, pp. 1-25][1]. Part of the area studied is pictured on the maps (Plates XV and XVI), which include the towns of Shoreham and Bridport in western Vermont. The reader is referred to the Ticonderoga, Brandon and Port Henry topographic maps published by the United States Geological Survey for a more detailed study of the localities listed in this paper. The district may be reached by automobile from the railroad at Middlebury, Vermont. Sections were made and fossils collected within the one hundred square miles of the area.

In the summer of 1921 three weeks were spent in field work, and in the summer of 1922 another three weeks were given to checking the previous work and adding to the data already acquired. The results of this work were published in the Thirteenth Report of the State Geologist of Vermont [2, pp. 71-86]. In the summer of 1924 three weeks were spent in the field. The field work has been supplemented by laboratory studies of the fossils from Shoreham and Bridport, and more particularly the

[1] The numbers within brackets refer to the bibliography attached to this paper.



Geological map of Bridport.

fauna of Fort Cassin at the mouth of Otter Creek, where an attempt had been made to show that the rocks are not Beekmantown in age, but belong to higher horizons.

I wish to acknowledge my indebtedness to Drs. Chester A. Reeds and the late Edmund O. Hovey of the American Museum of Natural History for their assistance in providing part of the time for field work. I also wish to thank the State Geologist for his help in furthering this study.

SHOREHAM AND BRIDPORT.

PHYSIOGRAPHY.

This area possesses the nature of a glaciated rolling plain which is known as the Champlain lowland. Aside from ground moraine, glaciation is evidenced by numerous undrained areas and marshes, by occasional waterfalls, and by a lack of systematic relation between the higher lands and the stream courses. It is probable that glaciation effaced many topographic features, perhaps filling and obliterating many small valleys and smoothing down many hills. Glaciation interrupted the cycle of erosion that was in progress before the ice period, and since the glacier withdrew, erosion has been renewed. A distinct north-south trend of the elevations is caused partly by the direction of the ice movement and partly by the attitude of the underlying rocks.

The topography and drainage are youthful, a youth that was superimposed upon surfaces that were in various stages of their erosion history before the ice affected them. Only one cycle of erosion is apparent, that being the post-Tertiary trenching of the streams in the New England plateau. The area represents only surface drainage.

STRUCTURAL GEOLOGY.

During the Cambrian and Ordovician periods the valley between the Green Mountains and the Adirondacks was partly filled with sediments which became consolidated by induration and pressure. At some unknown time after the cessation of deposition the Green Mountains were disturbed and moved westward. This movement caused the sediments in the valley to bow upward, forming a low dip to the west and a sharper dip to the east. As the westward movement continued the anticline broke along its axis and the east rocks rode up onto the west limb of the anticline. Continued westward movement of the Green Mountains pushed the east limb of the anticline farther onto the west limb. The rocks of the west limb were not greatly disturbed thereafter, but those of the east limb were forced on end, bent into drag folds and variously faulted. This movement ceased at some unknown time and the processes of erosion smoothed the

14 Rep

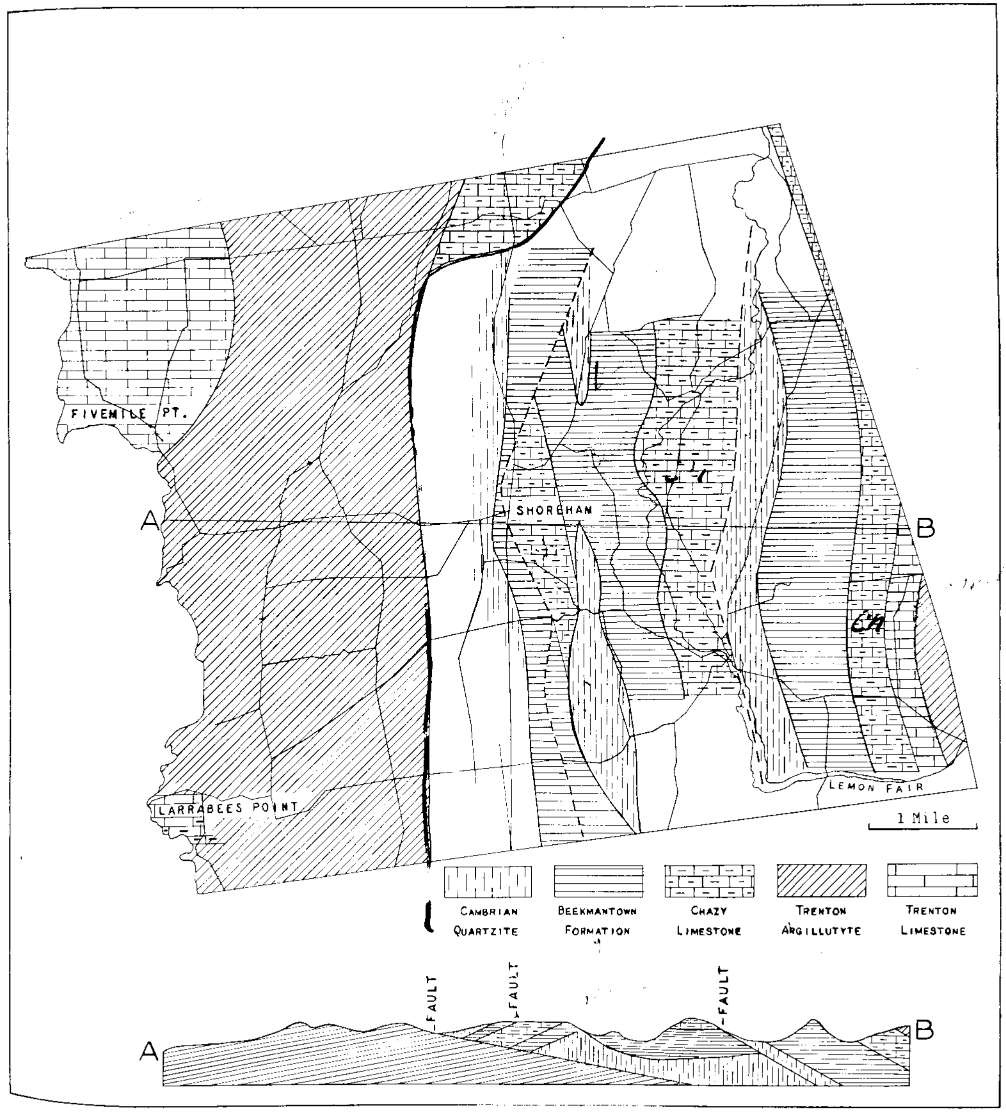
broken landscape. The observer now sees the gently sloping and little disturbed west limb of the anticline projecting from beneath the tilted fragments of the east limb. This in general was the course of events in this area after the close of the Ordovician.

The following illustrations (Plates XV and XVI) may serve to indicate the structural conditions which now obtain in Shoreham and Bridport. The rocks in southern Shoreham dip east and west on an anticline or drag fold at angles varying from 30° along the axis to 80° at places one-half mile to the east. The strike of the strata is generally N. 18° W. The field evidence indicates that the rocks have been subjected to great pressure from the east. In the great westward movement of the strata as a whole, many sections were dislocated and dragged behind. On the Whiting-Shoreham road sheared rock exposures and revoluted sections of strata indicate a long fault running east-west. One-half mile south of Shoreham Center a large section of strata has dragged behind in the westward movement of the rocks and is bounded on either side by transverse normal faults. These rocks lie upon Trenton beds which slope gently to the west.

An interesting exposure of the Beekmantown may be seen in the Bascom Ledge, which is situated two hundred feet south of the Laura Bascom farm at East Shoreham, Vermont. It consists of a high, steeply sloping bank facing the west. The strata dip 15° to the east and the strike is north-south. The rocks exposed consist of division D-3 and D-4 of the Beekmantown as defined by Brainerd and Seely or the Chazy of the writer. At the top of the bank the thin, tough shaly layers are plainly evident in division D-4. The intraformational conglomerate is disposed in patches throughout the rock. In one place I saw the coils of a gastropod one inch in diameter outlined in the conglomerate. The rock is distorted in some places. Half way down the slope the one-inch ridges of division D-3 are seen. At least two horizons in this stratum are very fossiliferous, but evidence of early life may be found in nearly all levels of the deposit. Twenty-five feet below the contact of the two beds the outlines of several coiled gastropods are etched upon the surface of the rock. One hundred feet below the contact the Chazy fossil, *Isotelus platymarginatus* Raymond, was found in abundance.

In Bridport the structure is not so complicated as it is in Shoreham. In the southern part of the town, along the Lemon Fair, the rocks have been bent into anticlines and synclines. The valley through which the Lemon Fair flows in going from Shoreham into Bridport is caused by a fault. Along the sides of this valley the strata have been greatly twisted and broken up. This fault may continue northeastward along the western margin of the river valley. At least one sheared outcrop of Chazy rock

PLATE XVI.



Geological map of Shoreham.

on the east side of Hemingway Hill tends to support this theory. In the east central part of the town the Chazy strata have been shoved up on end over the Trenton. The Cambrian quartzite of Grand View Mountain projects onto the Trenton in northeastern Bridport. In a traverse east from the southern end of Bridport village shale was encountered as far east as the east side of the road on the west side of the 500′ hill. The original bedding planes can be seen in the shale with the obscure cleavage planes of slate crossing them at an angle of 45°. Concretions were found in the shale, which in some places was crossed by thin layers of lime. Two beds of limestone were found on the hill. The west bed weathered gray, and the east bed weathered drab and was crossed with fine ridges of silica. The strike of the beds was N. 20° E. and the dip was 50° easterly. No fossils were found.

An anticline of shale was observed one-half mile east of Bridport on the road leading to Middlebury. The shale was composed of alternating bands of thick (1″) and thin (¼″) layers which were crossed by the cleavage planes of slate.

In a section which crossed Hemingway Hill to the Lemon Fair River drab, brown and gray strata of the Chazy were seen dipping steeply to the east to the edge of the river flats.

STRATIGRAPHIC GEOLOGY.

Owing to the presence of ground moraine and the Champlain clays this area does not possess many favorable outcrops for a successful study of its stratigraphy. The Cambrian and Ordovician periods are represented.

CAMBRIAN.

The Cambrian is a white, yellow and brown quartzite in Shoreham, and in northeastern Bridport it also contains red layers. It is very resistant and causes some of the highest elevations. In southern Shoreham the Cambrian forms the center of an anticline and is flanked on either side by the Ordovician. No evidence has been discovered to prove that the Ordovician lies disconformably upon the Cambrian, and it is quite possible that the Ordovician extends below this generally accepted level.

ORDOVICIAN.

LITTLE FALLS.

The first stratum of the Ordovician may be correlated with the Little Falls. Megascopically it is a dark, iron-gray magnesian limestone, more or less siliceous. Microscopically it is coarse-textured. Crystal outlines of the primitive rhombohedron denote dolomite which may be distinguished from the calcite matrix which has marked cleavage traces and lamellar twinning. The dolomite crystals show a yellowish-brown tint. Small cavities and crevices formed by shrinkage during dolomitization are filled with silica. Zones of growth may readily be seen in the dolomite crystals.

TRIBES HILL.

The second stratum may be correlated in part with the Tribes Hill. Megascopically it is a dove colored limestone mingled with light gray dolomite. Microscopically it is medium textured, and in a matrix of calcite there are sub-circular, finer-textured dark areas of dolomite.

BEEKMANTOWN.

The third stratum is Beekmantown and corresponds to Stage C, section 1 of Brainerd and Seely. Megascopically it is a gray, thin-bedded, fine-grained calciferous sandstone. Microscopically it is composed of fine-grained, sub-angular crystals of sand with an interstitial calcareous cement.

Stage C, section 2, is composed of a magnesian limestone in thick beds. Microscopically it is coarse grained with calcite crystals in various stages of dolomitization.

Stage C, section 3, is a light gray sandstone. Microscopically it is finely crystalline and is composed of sub-angular grains of beach sand.

Stage C, section 4, is a magnesian limestone containing chert. Microscopically it is finely crystalline. Small cavities and crevices formed by shrinkage during dolomitization are filled with silica.

Stage D, section 1, is a blue limestone. Microscopically it is medium grained and the crystals exhibit evidence of cleavage. Cloudy crystal outlines indicate the early stages of dolomite crystals.

Stage D, section 2, is a drab and brown magnesian limestone. Microscopically it is medium grained and is composed of calcite crystals in various stages of dolomitization.

CHAZY.

Stage D, section 3, belongs to the Chazy. It is a sandy limestone. Microscopically it is medium grained and exhibits calcite crystals interspersed with patches of silica.

Stage D, section 4, is composed of blue limestone beds separated from each other by thin layers of shale. The limestone is sometimes conglomeratic. Microscopically it is medium grained and shows dolomite crystals in a matrix of calcite crystals throughout which are scattered grains of silica. Wide bands of silica traverse the slice, which is also impregnated with bands of ferruginous material.

Stage E is a fine-grained magnesian limestone weathering drab, yellow or brown. Microscopically it is fine to medium grained. In a matrix of calcite crystals there are scattered dolomite crystals in various stages of development.

TRENTON.

The Trenton formation is composed of dark gray shales, limestones and shaly limestones.

PALAEONTOLOGY.

The oldest rocks of Shoreham and Bridport are sparsely fossiliferous. No fossils were found in the Cambrian. The Beekmantown has yielded a few forms, the most striking being the Cryptozoon. It is in the Chazy that we find more abundant evidence of former life, the gastropods and trilobites being the most prolific forms. The Trenton beds enjoy the distinction of being the most fossiliferous rocks in the area. In these strata one may find an abundance of bryozoa, brachiopods, cephalopods and trilobites. This in general is the palaeontologic aspect of the rocks in Shoreham and Bridport.

The following lists of fossils have been collected in the two townships and are assigned to the horizons of the Ordovician as indicated in part by the author [2, p. 4].

BEEKMANTOWN.

TRIBES HILL.

Cryptozoon steeli Seely.
Cryptozoon wingi Seely.
Holopea sp.
Orthoceras primigenium Vanuxem.

STAGE C, SECTION 1.

Scolithus minutus Brainerd and Seely.

STAGE D, SECTION 1.

Maclurites affinis (Billings).
Ophileta complanata Vanuxem.
Leperditia nana (Jones).

CHAZY.

Bathyurus extans Hall.
Bucania tripla Whitfield.
Eccyliomphalus lituiformis (Whitfield).

Isotelus platymarginatus Raymond, Stage D-3, Bascom Ledge, Shoreham.
Isochilina seelyi (Whitfield).

TRENTON.

The most favorable place to study the Trenton is at the ferry landing at West Bridport. Here a cliff twenty feet in height contains many layers which are filled with fossils. Specimens were collected at various levels on the face of the cliff and are listed below.

Water level, July 24, 1924.
Prasopora simulatrix Ulrich.
Plectambonites sericeus (Sowerby).

2 ft. level.
Orthis tricenaria Conrad.
Plectambonites sericeus (Sowerby).
Cryptolithus tessallatus Green.

3 ft. level.
Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman).
Orthis tricenaria Conrad.
Plectambonites sericeus (Sowerby).
Trematis terminalis (Emmons).
Calymene senaria Conrad.
Cryptolithus tessallatus Green.

4 ft. level.
Prasopora simulatrix Ulrich.
Palaeoglossa trentonensis (Conrad).
Platystrophia biforata (Schlotheim).
Plectambonites sericeus (Sowerby).
Trematis terminalis (Emmons).
Cryptolithus tessallatus Green.

5 ft. level.
Platystrophia biforata (Schlotheim).
Plectambonites sericeus (Sowerby).
Cryptolithus tessallatus Green.

6 ft. level.
Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman).
Palaeoglossa trentonensis (Conrad).
Platystrophia biforata (Schlotheim).
Plectambonites sericeus (Sowerby).
Zygospira recurvirostris (Hall).
Calymene senaria Conrad.
Cryptolithus tessallatus Green.

7 ft. level.
Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).
Cryptolithus tessallatus Green.

9 ft. level.
Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).

12 ft. level.
Plectambonites sericeus (Sowerby).

13 ft. level.
Platystrophia biforata (Schlotheim).
Plectambonites sericeus (Sowerby).

14 ft. level.
Plectambonites sericeus (Sowerby).
Zygospira recurvirostris (Hall).

15 ft. level.
Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).

16 ft. level.
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).

17 ft. level.
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).
Isotelus gigas deKay.
Cryptolithus tessallatus Green.
Endoceras proteiforme Hall.

18 ft. level.
Prasopora simulatrix Ulrich.
Cryptolithus tessallatus Green.

19 ft. level.
Plectambonites sericeus (Sowerby).

20 ft. level.
Dalmanella testudinaria (Dalman).
Platystrophia biforata (Schlotheim).
Plectambonites sericeus (Sowerby).
Isotelus gigas deKay.

On the Bridport-Middlebury road, two miles from Bridport, an anticline of Trenton limestone is exposed. The rocks at this locality yielded *Prasopora simulatrix* Ulrich, *Dalmanella testudinaria* (Dalman) and *Cryptolithus tessallatus* Green.

Another locality of note is in the northwest corner of the town of Bridport where the Trenton rocks forced up by frost action have been picked up in the fields and utilized in making stone walls. The following list of fossils was collected from these walls.

Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman)
Schizocrania filosa Hall.
Plectambonites sericeus (Sowerby).
Zygospira recurvirostris (Hall).
Conularia trentonensis Hall.
Sinuites cancellatus (Hall).
Calymene senaria Conrad.
Cryptolithus tessallatus Green.
Othoceras amplicameratum Hall.
Orthoceras tenuitextum (Hall).

In the northwestern part of Bridport the limestone is succeeded by a shaly limestone which is typically exposed on the Herman Smith farm where *Glyptograptus amplexicaulis* (Hall) was found.

THE GEOLOGY OF FORT CASSIN.

INTRODUCTION.

The geology of Fort Cassin is included in this paper because it has a definite bearing upon the geology of the townships of Shoreham and Bridport. A map of the geology of the region about Fort Cassin [3, p. 297] shows that the rock forming the peninsula is an isolated section of strata connected to the mainland by alluvium deposited at the mouth of Otter Creek. Brainerd and Seely [1, p. 20] correlated the beds at Fort Cassin with the upper part of stage D of their Beekmantown in Shoreham. I have accumulated evidence to show that the Fort Cassin beds have been in part erroneously correlated with this horizon [2, pp. 79-83]. By studies of the Fort Cassin type and figured specimens in The American Museum of Natural History and fossils collected in the field it is hoped to demonstrate the true ages of the Fort Cassin strata.

Beginning at the top, the succession of beds at Fort Cassin is as follows:

BLACK RIVER.

Dolomite weathered yellow .... 3′+
Black siliceous limestone .... 6′

DISCONFORMITY.

CHAZY.

Thin, shaly limestone merging into massive beds at the top..34′
Impure limestone with steel-gray appearance on fresh fracture, but weathering to a rusty color .... 6′
Sandy limestone weathering in parallel ridges one inch apart. Dip 5° south on the northwest point ....10′+

Considering its interest in geological history a short account of the recent history of Fort Cassin may not be amiss in this Report. In the course of the War of 1812-14 a small breastwork was thrown up on the north side of the mouth of Otter Creek where Lieutenant Cassin of the navy and Captain Thornton of the artillery with 200 men repulsed a large British force sent out from Canada to destroy the American fleet fitting out at Vergennes. Macdonough was at this time at Vergennes, and as soon as he was informed that the British flotilla had entered the lake, he ordered Lieutenant Cassin with a small group of sailors to reinforce Captain Thornton who had been sent from Burlington with a detachment of light artillery to man a battery which had been erected at the mouth of Otter Creek, or as called by the French, *La Riviere aux Loutres*. A brigade of Vermont militia was also ordered out and was advantageously posted to oppose the enemy in case he should attempt to land. At daybreak on the morning of May 14, 1814, eight of the British galleys and a bomb sloop anchored off the mouth of Otter Creek and commenced a warm fire upon the battery, which was promptly returned. A brisk cannonade was kept up by both parties for one hour and a half when the attack was abandoned. [6, pp. 198-199, 207].

The original breastwork was composed of slabs of rock collected along the shore and was covered with earth dug out from behind this enforcement. All that now remains of the original fortification is a low ridge of earth on the southwest point of the Fort Cassin promontory.

It was not until 1886 that further notice concerning Fort Cassin was published. At this time Professor R. P. Whitfield, Curator of the Geological Department in The American Museum of Natural History, described [3, pp. 300-345] a collection of fossils which had been made at this locality by Professors G. H. Perkins and H. M. Seely. This collection has been the object of interest and discussion ever since.

PALAEONTOLOGY.

The faunal aspect of the Fort Cassin fossils suggests that they are about Trenton and Chazy in age. A large *Isotelus* and several large nautiloids are enclosed in a black matrix similar to the Black River rock. A loosely coiled gastropod, *Eccyliomphalus,* lies half buried in a matrix of steel-gray appearance resembling the rock of the Chazy formation. A trilobite with genal spines from the thin shaly limestone is a type closely allied to the large trilobite at the top of the series, which is *Isotelus maximus* Locke, a form not known to exist below the Black River. The trilobite from the thin shaly limestone is comparatively small in its adult stage and most probably lived in the Upper Chazy seas. It is *Isotelus platymarginatus* Raymond (Plate XVII, fig. 2). This trilobite has been called *Isoteloides whitfieldi* [7, p. 36], which is supposed to occur in the Beekmantown formation. Its most striking characteristics are long genal spines and a semicircular pygidium. The cranidium has an acute angle anteriorily and is not rounded as according to the description of *Isoteloides whitfieldi.* An ontogenetic series of the pygidium shows that it varies but little in shape throughout life. During the young or nepionic stage the length of the pygidium increases in proportion to its width. The maximum length in proportion to width is in the neanic stage, when the pygidium is three-fourths as long as wide. The relation of length to width decreases slightly in the meta-neanic stage and continues in this proportion throughout its ephebic and gerontic existence. The axis of the pygidium displays slight annulations in young, exfoliated specimens and none in those forms which have not been exfoliated. In well preserved adults the axis is smooth and shows no annulations. The figure (Plate XVII, fig. 2) is a restoration based on several fragments. The species occurs abundantly in thin layers at the base of the thin shaly limestone.

During field work at Fort Cassin a few fossils not previously known from this locality were discovered. A specimen of *Streptelasma corniculum* Hall (Plate XVII, fig. 1, × 2) was found among the weathered stones on the shore. Another weathered specimen was *Actinoceras bigsbyi* Stokes (Plate XVII, fig. 3, × ½). These are typical Black River fossils. The cephalopod is seen in longitudinal section. The endosiphosheaths expand upward from the base in a siphuncle which is four and one-half inches across its widest part. On the reverse side of the specimen the steeply sloping septa may be seen, but the outer walls are absent. These fossils are not known to occur in the Beekmantown.

While the foregoing discussion is based on my field work and laboratory studies of collections which I made, the most important part of this study is founded on an examination of the Fort Cassin type and figured specimens in The American Museum of Natural History.

Of the forty-six species which are known to occur in the black siliceous limestone near the top of the Fort Cassin series, thirty-five were described as new by Whitfield [3, pp. 300-345;

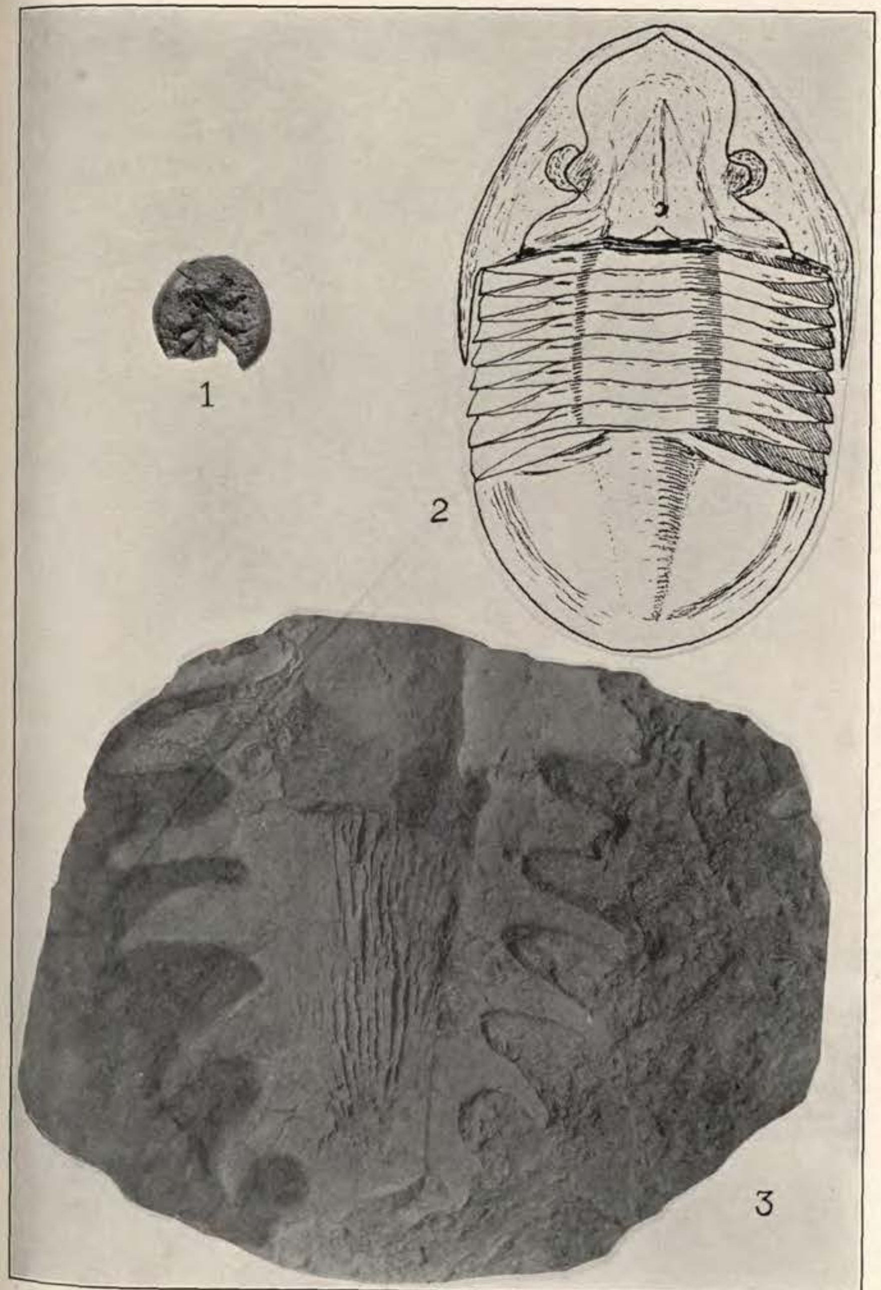


Fig. 1. *Strephelasma corniculum* Hale.
Fig. 2. *Isotelus plalymarginatus* Raymond.
Fig. 3. *Actinoceras bigsbyi* Stokes.

4, pp. 29-39]. Twenty-nine of the new species occur only at Fort Cassin. The others are doubtfully identified [5] or are identified with species occurring in localities in Canada where the stratigraphy is not exactly determined. All of the species from the steel-gray bed were given new names. It is seen that out of fifty-two species found at Fort Cassin, forty-one were described as new. Such a discovery in this region would be doubtful. It is seldom, if ever, that we find from seventy-nine to one hundred per cent. of the fossils occurring in a formation in a fairly well-known region are new species.

It was discovered that many of the Fort Cassin fossils were strikingly similar to Trenton forms, and on close inspection some of them could be identified as species which occur only in the Trenton rocks. Chazy fossils were also found in the collection. An effort was made to compare each specimen with Trenton or Chazy species, and as the work progressed the evidence became more and more conclusive that the Fort Cassin type and figured specimens belonged to the Trenton and Chazy formations. Although this work is still in progress, a tentative list is given below with the old names at the left and the new names a little below and to the right of each name which has been changed.

BLACK RIVER.

Rhinopora prima Whitfield.
    Receptaculites oweni Hall. (Impression of central core.)
Dalmanella (?) *evadne* (Billings).
    Plectambonites sericeus (Sowerby).
Polytoechia apicalis (Whitfield).
    Dalmanella testudinaria (Dalman).
Syntrophia lateralis (Whitfield).
Archinacella simplex (Billings).
Clisospira lirata Whitfield.
Eccyliomphalus perkinsi (Whitfield).
Eccyliopterus volutatus Whitfield.
Eotomaria ? cassina (Whitfield).
Euconia etna (Billings).
    Clathrospira subconica (Hall).
Euomphalus ?? circumliratus Whitfield.
    Trochonema umbilicatum (Hall).
Fusispira obesa (Whitfield).
    Holopea paludiniformis Hall.
Helicotoma similis Whitfield.
Hormotoma obelisca (Whitfield).
    Fusispira subfusiformis (Hall).
Maclurites acuminatus (Billings).
Maclurites affinis (Billings).
    Maclurites crenulatus (Billings).

Murchisonia ?? prava Whitfield.
  Hormotoma bellicincta (Hall).
Plethospira arenaria (Billings).
  Holopea ventricosa Hall.
Plethospira cassina (Whitfield).
  Raphistoma rotuloides (Hall).
Raphistoma compressum Whitfield.
Raphistoma hortensia (Billings).
  Liospira vitruvia (Billings).
Scenella cassinensis Bassler.
Tryblidium ovale Whitfield.
Tryblidium ovatum Whitfield.
Cameroceras brainerdi (Whitfield).
Cyrtoceras ? acinacellum Whitfield.
Cyrtoceras confertissimum Whitfield.
Cyclostomiceras cassinense (Whitfield).
  Poterioceras apertum Whiteaves.
Cyclostomiceras minimum (Whitfield).
  Oncoceras constrictum Hall.
Eurystomites kelloggi (Whitfield).
  Plectoceras ? undatum (Conrad).
Eurystomites rotundus Hyatt.
  Plectoceras ? undatum (Conrad).
Orthoceras bilineatum Whitfield.
  Spyroceras bilineatum (Hall).
Orthoceras explorator Billings.
  Orthoceras multicameratum Emmons.
Orthoceras sordidum Billings.
Orygoceras cornuoryx (Whitfield).
Piloceras explanator Whitfield.
Protocycloceras whitfieldi Ruedemann.
  Spyroceras bilineatum (Hall).
Schroederoceras eatoni (Whitfield).
  Plectoceras ? undatum (Conrad).
Schroederoceras cassinense (Whitfield).
  Plectoceras ? undatum (Conrad).
Trocholites internistriatus (Whitfield).
  Plectoceras ? undatum (Conrad).
Tarphyceras seelyi (Whitfield).
  Plectoceras ? undatum (Conrad).
Tarphyceras champlainense (Whitfield).
Tarphyceras perkinsi (Whitfield).
  Plectoceras ? undatum (Conrad).
Asaphus canalis Conrad.
  Isotelus maximus Locke.
Bathyurus longispinus Walcott.
  Amphilichas trentonensis (Conrad).
Eoharpes cassinensis (Whitfield).

[redacted]

Nileus striatus Whitfield.
Ribeiria compressa Whitfield.
Ribeiria ventricosa Whitfield.

CHAZY.

Protorthis ? cassinensis Whitfield.
  Dalmanella testudinaria (Dalman).
Protorthis ? minima Whitfield.
  Dalmanella testudinaria (Dalman).
Eccyliomphalus lituiformis (Whitfield).
Hormotoma ? cassina (Whitfield).
Bolbocephalus seelyi (Whitfield).
  Cf. Asaphus expansus Linnaeus.
Bathyurus perkinsi Whitfield.
  Bathyurus extans (Hall).
Bolbocephalus ? truncatus Whitfield.
  Bathyurus extans (Hall).

In the Princeton University collections I have seen *Bolbocephalus* Whitfield and *Isotelus platymarginatus* Raymond in the same piece of rock from the neighborhood of Plattsburgh, N. Y. (Loc., 133AA).

In conclusion, the foregoing evidence is offered to show that the rocks of Fort Cassin are not Beekmantown in age, but belong to the Chazy and Black River formations. In consequence, the upper part of Division D of Brainerd and Seely's Beekmantown, which has been correlated with the Fort Cassin rocks, must be other than Beekmantown in age; and it is suggested in this paper that it belongs to the Chazy.

BIBLIOGRAPHY.

(1) Brainerd, E. and Seely, H. M. 1890. The Calciferous Formation in the Champlain Valley, Bull. Amer. Mus. Nat. Hist., III, pp. 1-25.

(2) Foyles, E. J. 1923. Preliminary Report on the Ordovician Formations of Vermont, Report of the Vt. State Geologist, XIII, pp. 71-86.

(3) Whitfield, R. P. 1886. Notice of Geological Investigations along the Eastern Shore of Lake Champlain, Bull. Amer. Mus. Nat. Hist., I, pp. 293-345.

(4) Whitfield, R. P. 1890. Observations on the Fauna of the Rocks at Fort Cassin, Vermont, with Descriptions of a Few New Species, Bull. Amer. Mus. Nat. Hist., III, pp. 25-39.

(5) Bassler, R. S. 1915. Bibliographic Index of American Ordovician and Silurian Fossils, Bull. Smith, Inst., U. S. Nat. Mus., 92, Vols. I, II.

(6) Palmer, P. S. 1866. History of Lake Champlain, pp. 198-199, 207.

(7) Raymond, P. E. 1911. Notes on Ordovician Trilobites, Annals of the Carnegie Museum, VII, pp. 35-45.

STUDIES IN THE GEOLOGY OF WESTERN VERMONT.

Third Paper.

CLARENCE E. GORDON.

TABLE OF CONTENTS.

INTRODUCTION.

The present paper reviews chiefly some of the field relations among the rocks that make up the Taconic range and its foothills in Vermont. The rocks everywhere have been greatly altered and deformed by pressure. Except for relatively small dikes of basic igneous rock, which are not infrequent in the region, there are no exposed intrusions. While petrographic study has not been made to determine if the rocks possess any characters that might logically be explained as the result of deep-seated injection of igneous rock, there do not appear to any such and the alteration which the rocks have suffered seems to be due to the dynamic agency of pressure alone.

The Taconic mountains of Vermont lie in the southwestern part of the state and form one of four major physiographic divisions. East of the Taconic range is a relative lowland which is known as the Vermont valley. The valley separates the range from the western scarps and hills of the Green Mountain plateau. At the latitude of Brandon the Vermont valley merges with the

Champlain lowland, a broad region lying between the Green Mountains and the Adirondacks, and occupied in its western portion by Lake Champlain.

These main physiographic features of western Vermont appear to be primarily of structural genesis. The Vermont valley and Champlain lowland are, broadly speaking, sunken areas due to differential movement between the rocks that underlie them and those that form the rock masses that border them on the east and west. These ancient structural features are materially emphasized by the work of erosion which has taken advantage of down-sunken areas of relatively soft rocks. But the deformations which were responsible for these major physiographic divisions were subsequent to earlier ones which were of a different kind and which now have expressions in various minor features of the landscape. These more ancient deformations were due to the action of powerful forces of compression which jammed, folded, overturned and ruptured the rocks. This particular class of secondary features may be identified in all of the main divisions of the region.

The major problem in the geology of western Vermont is to correlate the rocks within and among the different divisions. In this task one may not ignore the various disturbances and changes which the rocks have undergone. In view of the probable existence of common secondary structural characters among the rocks of these geographically closely related divisions one might hope to be able to apply a structural key to the problem of the primary relations of the various rocks.

There is fortunately not always a sharp difference between formations found in the different divisions of the region, but rather either identity or transitions may be shown to exist among the rocks in contiguous portions of these divisions. In cases where correlation must be made without the aid of fossils such relations are, of course, very important. In other cases a marked lithological difference between adjacent formations occurs and proves very baffling. It is well to remember that early deformations and later erosion have undoubtedly produced many of the irregularities of the present surface which are explicable only in the light of the disturbances which the rocks have suffered.

The western margin of the Green Mountain plateau is marked by a formation which has as its prominent member in many places a massive quartzite. This is usually associated with thinly-bedded quartzite or schist. In the northern part of the state the quartzite member is less prominent and may be replaced by quartzitic gneiss or schist. Quartzite and schist entirely similar to those which form the margin of the plateau make up scattered hills along the eastern side of the Vermont valley and Champlain lowland, or occur in the floor of the valley itself. These rocks, on the basis of fossils that have been found at a few places in them, are regarded as belonging to the lowest division of the Cambrian system.

In the valley and the lowland quartzite or schist are frequently associated with dolomite, or a formation composed of interbedded dolomite and quartzite, and in some places dolomite and in others the interbedded series apparently succeeds the quartzite conformably. Along the margin of the plateau dolomite also lies at places on the quartzite; but the dolomite has not been so extensively preserved as in the valley and the lowland. The rocks making up the floor of the valley are separated from those of the plateau by faults. There can be but little doubt that the dolomite was once more widely distributed over the quartzite and its associates within the plateau.

The dolomitic rocks so characteristic of the Vermont valley extend through the eastern portion of the Champlain lowland as far north as Hinesburg and Charlotte townships, where by changes in such features as color and thickness of beds they seem to grade into the magnesian and quartzitic rocks of the "Red Sandrock" series of northwestern Vermont.

In the Vermont valley the interbedded dolomitic and quartzitic rocks of the Lower Cambrian extend close to the bases of the rugged eastern slopes of the Taconic range. In the Champlain lowland the members of the Red Sandrock series extend west to the great fault along which the Lower Cambrian rocks have been elevated against the Ordovician beds of the lake series.

The distribution and characters of the various rocks that form the surface of the Champlain lowland have already been somewhat fully described by the writer (see second paper). In general it appears that east of the great fault that runs for miles east of the eastern shore of Lake Champlain an ancient Cambrian surface has been partly restored by processes of thrust and that on this surface there now rest younger rocks which are intricately involved with the older ones through folding and shearing. Fossils are scare and even when found are often suggestive rather than conclusive. Formations have been sheared out in the process of thrusting and imbrication and inversion of rocks have been produced in the same way until it becomes very difficult in many cases to predicate primary relationships from present conditions.

In the southern portion of the Champlain lowland members of the lake series of Ordovician rocks, carrying fossils, extend east to Weybridge, Cornwall and Sudbury and are intermingled at the present eroded surface in these townships with schists, phyllites and quartzite which are very similar to rocks found in the northern part of the Taconic range. These terrigenous rocks are, indeed, practically although not actually continuous from Sudbury through Whiting and Cornwall to Weybridge. And in the northern portion of the Taconic range, in western Sudbury township and in Benson and Orwell, members of the lake series

carrying recognizable Chazy and Trenton fossils are intermingled in an irregular fashion with phyllites and schists like those of Cornwall and Weybridge. There is, therefore, not a sharp separation between the southern portion of the lowland and the northern part of the range, but the two merge into one another both topographically and geologically.

In the Champlain lowland the most southern outcrops of rocks that could be assigned to the Red Sandrock series occur in northeastern Bridport and northwestern Cornwall, forming the southern extension of the red quartzite of Snake Mountain into these townships. The black schists and lighter-colored phyllites which have been mentioned as forming the northern continuation of the rocks of Sudbury into Whiting, Cornwall and Weybridge lie on meridians about two miles east of the red rock of Snake Mountain. The red rock of Snake Mountain is supposed to be of Lower Cambrian age and according to the writer's view the schists and phyllites intermingled with the Ordovician limestones in Weybridge and Cornwall are probably of similar age. The questions of what was the primary relation and what is the present structural relation of the red rock to the phyllites may best be discussed later.

Along the western side of the Vermont valley, usually outcropping west of the general western margin of the dolomitic rocks that have been mentioned as forming such a large part of the hard rock surface of the valley, but sometimes occurring among the dolomitic series, are calcareous rocks belonging to a formation from which at various places throughout the valley and in the southeastern portion of the Champlain lowland marble has been quarried. The various rocks which are here correlated with one another are not always marble; but since they all seem to belong to the same general formation the latter may be conveniently called the "marble formation." These marble rocks of the western side of the Vermont valley extend westward into the Taconic range along the valleys of certain streams and at places through relatively high col-like passes. At the northern end of the range in Sudbury they seem to join at the present surface with fossiliferous rocks of the lake series; but south of Sudbury in the higher portions of the range they do not now extend very far west and indeed are usually fragmentary. Detached areas of various dimensions occur within the range all the way from Pittsford to Sandgate. The rocks of the marble formation have yielded fossils in only a few places. On the basis of such fossils as have been found and from other considerations the marble formation has been broadly classified as a part of the Ordovician system. Its probable structural relation to the dolomitic rocks that lie to the east of it has been discussed in the first paper under this title.

The rocks of the Taconic range and its outlying hills altogether make up a vast mass of metamorphosed terrigenous sediments of various kinds. While it is possible in a rough way over large areas to map some of these rocks as distinct from others, there is still a good deal of overlapping of the various kinds at the present surface. In the main portion of the range the rocks are prevailingly coarse schists with phyllitic, quartzitic and occasionally conglomeratic variants. These rocks have been called the "Berkshire Schist." West of the main range and some of its higher foothills the schist at the present surface is replaced over large areas by slates, but sharp boundaries are everywhere lacking. The broad area west of the main range and from which slates are so largely quarried, is known as the "slate belt." The slate belt has been described as largely formed of Lower Cambrian rocks with many extensive outliers of terrigenous Ordovician slates or schists. The Berkshire Schist has been described as lying above the marble formation and as belonging to the Ordovician system.

The assignment of certain terrigenous rocks of the slate belt to the Ordovician system has been on the basis of the discovery of fossils, mostly graptolites, at scattered localities, but large areas have been mapped as Ordovician in which only one or two fossil localities are known. In view of the relatively small number of fossil localities, question arises as to the extent of Ordovician terrigenous rocks in the slate belt. Large areas have clearly been mapped as Ordovician by reason of lithological similarity of the rocks to those which have yielded fossils. It often appears possible to make a lithological distinction between these terrigenous rocks which are called Ordovician and others which are called Cambrian; at other times separation in the field is not easy.

For the rocks of the slate belt which are called Cambrian lithological characters have also been extensively used; but fossil localities have been reported more frequently among such rocks.

The probable extent of Ordovician terrigenous rocks in the slate belt, and the relations which such rocks have on one hand to certain limestones carrying Ordovician fossils and, on the other, to the associated rocks of known or probable Cambrian age, are questions inviting further investigation. Only incidental mention will be made in this paper of these matters.

In the northern part of the slate belt detached areas of calcareous rocks, many of them with distinct fossils and others without, are associated with terrigenous rocks in apparently very much the same relations as that shown between the areas of calcareous rocks and their associated schists within the main range.

The Berkshire Schist is not a homogenous formation and it is difficult to distinguish some of its members from rocks found in the slate belt and from others found along the western margin of the Green Mountain plateau and in its foothills. It is not easy to define the boundaries of the so-called Berkshire Schist. The geological age of the formation has been assigned from structural relations which it has seemed to have to other rocks. On the eastern side of the Taconic range the schist has been supposed to rest on the marble formation. Again, the schist has been described as showing transition, at some places west of the main range, into less altered terrigenous rocks that have been put in the Ordovician system on the basis of fossils which have been found in similar terrigenous rocks.

On the supposition that the schist is younger than the marble, it is surprising to note the absence of any similar rock over most of the Champlain lowland north of the Taconic range; for if the schist is of the age which has been claimed for it then it is difficult to imagine why, if such kinds of rocks as compose the Taconic range were there laid down above the limestone now represented by the marble, similar rocks were not deposited on Ordovician limestones over what is now the Champlain lowland. It is not easy to imagine that terrigenous rocks like the schists of the range were ever more widely distributed in the Champlain lowland above the calcareous rocks and were subsequently eroded. In the first place, there appears no good reason why such rocks should have been so extensively eroded over one part of the region and so fully preserved in another adjacent to it unless we assume that such rocks were very much thinner in one part of the region than in the other, or that the lowland was once at a relatively higher elevation than the Taconic region and that the present structural relation between the two was brought about after extensive erosion from what is now the lowland of rocks like those of the Taconic range. Neither history seems probable. Moreover, such rocks as are now found in the lowland and which can be correlated with the terrigenous rocks of the Taconic range do not appear to lie above the calcareous rocks with which they are associated, but on the contrary seem to be beneath them.

In the accounts which have been given of the occurrence of members of the marble formation at various places within the Taconic range the interpretation has been made that the marble is now exposed at the surface because of erosion of overlying schist. This may be the case at certain places, but at no place which the writer has seen is there any proof of it. In a region of thrust displacements it would not be extraordinary if an older schist formation was driven over a younger marble, but such a relation has not been observed within the range.

In northern Sudbury, and in Orwell, Whiting, Cornwall and Weybridge, members of the schist formation seem to emerge from beneath a covering of marbly or other calcareous rocks. In Sudbury, Orwell and Benson the field relations seem hardly to permit any other interpretation than that calcareous rocks of Ordovician age rest on a schist-phyllite formation. As will be explained more fully later there are reasons for thinking that the apparently inferior position of the marble on the east side of the Taconic range and at places within it is the result of displacements which have occurred between the calcareous rock and the schist. It may be noted at this place that definite sedimentary contacts are difficult to find and that the schists of the Taconic range and the oldest rocks of the slate belt seem nowhere to have their bases positively exposed.

The idea has been advanced that the so-called Berkshire Schist as a formation represents the entire Ordovician series of the slate belt, which is regarded as including various terrigenous rocks and limestones of Chazy and Trenton, and possibly Black River, age. This conception is difficult to support for many reasons.

For any further account of the relations among the rocks within the Vermont valley or the Champlain lowland the reader is referred to the other papers published under this title.

OBSERVATIONS MADE BY THE WRITER WITHIN THE TACONIC REGION.

General plan of discussion. As in previous papers, county and township names will be used as headings for purposes of description of the various parts of the region. Citation of localities will be based on the topographical sheets of the United States Geological Survey. It should be understood that the use of county and township names does not imply a complete description of the various geological features of the different towns named. The object of the paper is to discuss some apparently significant field relations that bear upon the interpretation of the structure of the Taconic region and upon the correlation of some of the rocks with those of adjacent or neighboring portions of western Vermont.

RUTLAND COUNTY.

Pittsford Township.

(Castleton topographic sheet.)

Location. Pittsford lies south of Brandon. It is bounded on the east by Chittenden, on the south by Rutland, Proctor and West Rutland, and on the west by Hubbardton and a small triangular portion of the township of Ira, which projects northward between it and the township of Castleton.

General description. The eastern part of Pittsford includes a portion of the western margin of the Green Mountain plateau. Its central part is occupied by a portion of the valley of Otter Creek. From the plain of the river the land rises gradually westward to the base of the steep eastern slopes of the Taconic range which extends through the western part of the township.

The rocks of the plateau margin and the Vermont valley in Pittsford have been only casually inspected. Those of the plateau join at the south with the quartzite and schist east of Rutland and northward join with those of Brandon. Coxe Mountain is the southern portion of an outlying ridge of quartzite and schist extending from Pittsford into Brandon. The ridge is separated from the steep margin of the plateau by the valley of Sugar Hollow Brook. The rocks of the ridge are interesting because, taken all together, they form an assemblage that in large measure has its counterpart in the rocks found in the Taconic hills in Sudbury and in other parts of the range. The valley of Sugar Hollow Brook is a synclinal trough modified by faulting and has its counterpart at several places north of Pittsford along the margin of the plateau. Numerous outcrops of dolomite, which has been described as lying above the basal terrigenous formation of quartzite and schist in the Vermont valley, occur along Sugar Hollow Brook as remnants of a large amount of similar rock that once filled the brook valley. The dolomite is at present only sparingly found in the high land east of Sugar Hollow; but it may be traced from the brook eastward up the steep slope of the mountain through a col to the upland. All the topographic and geological features around Sugar Hollow clearly indicate that the rocks forming the floor of the hollow and those of ridge west of it are dismembered parts of the plateau proper. Dolomite is found at places along the ridge west of Sugar Hollow, but for the most part has been eroded.

On the west the Coxe Mountain ridge slopes to the plain of Otter Creek. This western slope is drift covered. West of the creek is hilly land whose surface is formed of dolomite or interbedded dolomite and quartzite, and west of these by calcareous rocks belonging to the marble formation. Similar rocks undoubtedly underlie the plain along Otter Creek, for such rocks outcrop in Brandon on meridians occupied by the flood plain deposits in Pittsford.

The dolomite and interbedded rocks in the central and west central portion of Pittsford are counterparts of the dolomitic rocks of the eastern part of the town and presumably at some depth beneath the dolomitic rocks of the valley lies the terrigenous formation of the plateau.

Studies which have been made of the valley rocks in Brandon township have shown that the structural relations between the dolomites, which are probably of Lower Cambrian age, and the marble, which is probably of Ordovician age, are very complicated. In general the rocks are much involved through folding and thrusting. Satisfactory evidence of thrust overlap of the older dolomites on the marble may be seen in the neighborhood of Brandon. Many considerations could be offered to show the probability that the relations between the marble and dolomite all along the Vermont valley are not as simple as some descriptions of the region would have us believe.

South of Pittsford, partly in Rutland, partly in Proctor and West Rutland townships, is a ridge that separates a narrow valley which extends from Center Rutland village north through Proctor, and which has been called the Center Rutland valley, from another narrow valley which has been called the West Rutland valley. This ridge is largely made up of schist and at its northen end merges with the foothills of the Taconic range in the western part of Pittsford, which are composed of similar schists. Outcrops of marble occur at the eastern base of the ridge in Pittsford and the marble has been interpreted as passing beneath the schist. On the summit of the ridge near the boundary line between Pittsford and West Rutland are patches of calcareous rocks which seem to belong to the marble formation. These outcrops are not extensive and have been interpreted as interbedded members of the schist formation.

West Rutland valley is that occupied by the headstream of Castleton River. It extends into the southwestern part of Pittsford. The floor of the portion of the valley which lies in Pittsford is formed of the schist formation. But just south of the Pittsford line are apparently detached outcrops of marbly rock and farther south are the great marble quarries of West Rutland. According to the idea that the schist formation is younger than the marble, the absence of the latter in the portion of the valley of Castleton River that extends into Pittsford would be explained as due to the fact that erosion had not gone deep enough to expose the marble, while farther south it had. According to the same idea the marble would not be sought over the schist areas in the hilly land of western Pittsford, except as it might now occur at the surface as the result of irregularity of deformation which left the marble formation at certain places in such position that it was reached and exposed by erosion. The idea that there was any such irregularity of deformation would grow out of the circumstance that marble occurs here and there within the areas largely occupied by the schist formation, on the assumption that the schist is the younger rock. An alternative view, of course, is that small patches of marble or calcareous rock occurring within the schist are remnants of erosion of a formation that lay above the schist and that the latter is the older.

In previous papers, considerations have been offered in support of the view that a schist formation in all essential characters like that which forms the ridge between the Center Rutland and the West Rutland valleys and that which makes up the terrigenous areas in western Pittsford is actually subjacent to calcareous rocks which appear to belong to the marble formation of the Vermont valley. In southwestern Brandon and in Sudbury the field relations leave little doubt that the marble formation is superjacent to the schist. The latter joins southward with similar schist in Hubbardton, which joins with that in the western part of Pittsford.

Within the schist area of western Pittsford one other outlying patch of the marble formation was found west of the band of outcrops of marble rocks on the west side of the valley along the schist border. This small area lies about a mile and a half west of Fowler, near the base of the eastern slope of Biddie Knob. The marble is plainly surrounded by the schist formation. A quarry, now unworked, has been opened in the marble at this place and considerable stone was apparently removed. It did not prove possible to determine whether the marble lies on the terrigenous rock and the field relations were too vague to warrant any generalizations on the basis of this outcrop taken by itself, as to relations of schist and marble.

Other than the features that have been elsewhere described for the terrigenous rocks of the Taconic hills and which could serve as a basis for correlating them with similar rocks in the eastern part of the Vermont valley and along the margin of the plateau, only one other thing was noted in Pittsford. One-fourth of a mile north of Butter Pond, and about two and a half miles north of the Pittsford and West Rutland line, near the summit of a hill west of the road to Fowler, layers of quartzite, schist and dolomite, the last subordinate but very evident, are infolded with schistose quartzite. The interbedded rocks just mentioned resemble strongly similar ones found at the base of the interbedded series of dolomite and quartzite in the eastern part of Brandon and elsewhere, and from the intimate relation which they have to the schist formation were regarded as furnishing additional evidence in support of the correlation of the schist at the west with similar rocks east of the Vermont valley.

Rutland and Proctor.

(Rutland and Castleton topographic sheets.)

Location. Rutland lies south of Pittsford and joins Mendon on the east, Clarendon on the south and West Rutland and Proctor on the west.

General description. North of the city of Rutland the surface rocks are quartzite with subordinate schist and dolomite and are the counterparts of similar rocks in the eastern part of Pittsford. These rocks north of Rutland have synclinal arrangement with dolomite on top. They are apparently separated from the rocks of Pittsford by a displacement across the strike, the Pittsford rocks being on the downthrow side. Northwest of the city of Rutland the quartzite and schist form a ridge known as Pine Hill. The eastern slope of this hill is largely quartzite, which frequently extends eastward at the surface to and across the road from Rutland to Pittsford Mills. The quartzite is succeeded eastward by the dolomite, but the quartzite bends round the dolomite at the north and joins with other quartzite on meridians farther east.

The quartzite of Pine Hill is interchangeable along and across the strike with a schist like that which forms the ridge between Center Rutland and West Rutland valleys. In Pine Hill the quartzite and schist each usually makes masses so large that they appear as distinct formations and have been interpreted and mapped as such and as of different age. The quartzite carries subordinate lenses of black schist not easily if at all distinguishable from the large schist masses. On the western slope of the Pine Hill ridge the quartzite in general now forms scarps above an apparently continuous band of the schist. East of Proctor the western slope of the hill descends over interbedded dolomites and quartzites which join with those that prevail around the village. Marble, however, outcrops at numerous places between the schist and the interbeddded rocks on the western slope of the hill.

The fact that a thrust at Pine Hill has thrown the terrigenous rocks against the marble and interbedded rocks that lie west of them has been recognized; but the schist has been interpreted as of younger age than the various calcareous and dolomitic rocks to the west of it and also as younger than the quartzite that lies above it. If this is the case then the absence of schist above the calcareous and dolomitic rocks of the valley in Pittsford, north of Proctor, must seemingly be accounted for by erosion. It is not easy to understand, if the schist is younger than the marble and normally lies above it in the Taconic range, why masses of schist as thick at least as those of the range should not once have covered the rocks now forming the floor of the Vermont valley in Pittsford and Brandon.

The terrigenous rocks of Pine Hill appear not to differ essentially from those which make up the ridge that begins with Coxe Mountain in Pittsford and extends northward into Brandon. In the latter ridge schist and quartzite are interchangeable along the strike and the schist has nowhere any association with the marble formation.

The relations of the dolomitic and calcareous rocks around the village of Proctor are very complicated and almost defy any attempt at description. Interbedded quartzite and dolomite and massive dolomite are intermingled with marble in an irregular manner and it did not seem possible to determine the structural relations from the present arrangement. Numerous outcrops of the interbedded series show the effect of strong compression in jammed and closely-folded beds, which often stand nearly vertical. Heavy masses of dolomite have apparently not been so strongly folded. The marble everywhere indicates great alteration. The inbedded rocks and most, if not all, the dolomite is correlated with the Lower Cambrian, as are similar rocks around

Brandon and in other parts of the Vermont valley. The marble is regarded as of Ordovician age.

South of Proctor village the Center Rutland valley narrows and bends somewhat to the eastward towards Center Rutland village, crossing diagonally the schist and quartzite north-northwest of the village. The calcareous rocks appear to run out at the surface southward and from relations shown by the terrigenous rocks east and west of Otter Creek near Center Rutland it is thought that these rocks form the hard rock surface beneath the mantle of surface deposits west of Center Rutland village. The schist which makes up the ridge between Center Rutland and West Rutland valleys outcrops at its southern end near the junction of the road from Center Rutland to West Rutland with the road to Proctor that runs along the west side of Center Rutland valley and these outcrops are on meridians only a little way to the west of those occupied by similar schist or by quartzite on the east side of the valley. The schist outcrops at many places along the road on the west side of Center Rutland valley, and at some places on contours nearly as low as the level of the plain of Otter Creek. The west side of the valley was searched for places that might show the marble passing beneath the schist, but such were not found. It seemed as though, if the schist lies on the marble, it would be found capping the marble at some places.

In the southern half of the schist ridge, west of Center Rutland valley, the eastern side emerges by fairly gentle slope from the lowland along the creek. West of Proctor village and on parallels somewhat north and south of it the eastern side of the ridge is abrupt and has much the appearance of a fault-line scarp, and was so interpreted.

No patches of calcareous rocks were found on the schist ridge west of Center Rutland valley, within the towns of Rutland or Proctor.

West Rutland Township.

(Castleton topographic sheet.)

Location. West Rutland joins Pittsford on the north and Proctor and Rutland on the east. On the south it joins with a part of Clarendon, but on this side is largely bounded by the township of Ira. Which also extends as a triangular area on the west and separates it from the township of Castleton.

General description. This township includes most of the so-called West Rutland valley celebrated the world over for its marble quarries. The name West Rutland valley is most often applied to the trough occupied by the headstream of Castleton River, north of the pass in the Taconic range through which the river flows westward, and to the southern extension of the Castleton River lowland to West Rutland town, but as a topographic feature the valley extends much farther south between the Taconic range on the west and the Danby-Clarendon ridge on the east.

The structure of the Castleton River valley north of West Rutland has been interpreted as anticlinal and the marble has been described as probably passing beneath the schist of the Taconic range. On the basis of a certain kind of interfingering of marble and schist at the northern end of the valley, where the marble runs out at the surface near the Pittsford line, it has been suggested that the anticline is probably made up of minor folds.

At best the field relations and minor structural features are far from being decisive and leave much to be guessed at, so that the general structure has been and may be surmised rather than proved. The present arrangement of the rocks and the distribution of the surface mantle are such that structure must largely be interpreted on the basis of probability, so that different views are possible according to the method of approach to the problem. If the view is taken that the schist is younger than the marble the structure would be explained in a different way from that which would proceed on the idea that the schist is older.

Certain structural features which have been cited in support of the view that the schist is younger than the marble do not seem to be convincing. In favor of the opposite view there are certain considerations which may not strike others as convincing. Once more to be noted is the apparent absence to any noteworthy extent of the schist formation over the lowland of Castleton River in the West Rutland valley. If the schist ever lay conformably on the marble within the area now occupied by the valley it seems as though there should be more evidence even in this narrow valley, of the resistant formation that forms such high ridges on the east and the west.

The assumption has been that the schist has all been eroded from the marble over most of the length of the valley and that the schist that now forms the valley floor just north of the Pittsford line now lies on marble which has not been exposed. In view of the apparent inferior position of the schist in Sudbury and Orwell to calcareous rocks that may be broadly correlated with the marble, the schist formation may be imagined as passing beneath the marble of the West Rutland valley. According to this view the schist floor of the valley north of the Pittsford line has been exposed by erosion of the marble and the reason why it is not found in the valley farther south would then be because the schist passes southward beneath the marble and emerges in the valley again only south of West Rutland town.

The marble formation outcrops within the valley from a point just south of the Pittsford line to a parallel about a mile south of West Rutland town. North of the town the outcrops occur along the eastern side. In the western part of the valley throughout the distance just mentioned a broad band of surface material separates the marble from the exposed portions of the schist at the base of the eastern slope of the Taconic range. What underlies the surface deposits is not known. Schist descends practically to the level of the plain of the river, along the road that runs on the western side of the valley, and near the Pittsford line forms one or more patches east of the road. If the marble formation has fairly regular anticlinal structure, with sufficient northerly pitch to pass beneath the schist in southern Pittsford it would seem as though the schist would not form a practically continuous outcrop as it now does, at such a low level, along the western side of the valley; but that it would be interrupted by the marble and that the latter would emerge at places from beneath the schist. Schist contact on marble seemingly might also be looked for in the northern part of the valley.

The most northern outcrops of calcareous rock that was noted in the valley occurs on the eastern north-south highway, just a little way south of the Pittsford line. It forms a knoll-like mass and on the north and west is surrounded by lower land. The field relations suggest that it is a portion of a larger mass of similar rock that has survived erosion rather than an inlier of marble in the schist formation. Unless minor folding is involved, which does not seem likely, if the schist is the younger rock, it should here occur at the topographic level of the softer rock, or even higher. The greater frequency of outcrops and abundance of marble along the eastern side of the valley may be accounted for through protection afforded the marble by reason of a certain amount of overlap occasioned by inversion of the eastern schist due to folding or thrusting rather than as the result of a normal capping of marble by schist. For, if the structure of the valley is that of fairly simple and regular anticline of marble overlain by schist, the marble should seemingly be preserved at similar levels, at places at least, along the western side of the valley as a result of protection given by the schist.

The eastern slope of the Taconic range which lies west of the West Rutland valley is in most places steep and often abrupt. As a whole, it offers strong suggestion of a fault line or zone along which the rocks of the West Rutland valley were dropped. The amount of displacement was not the same at all places. According to this idea the schist forming the floor of the valley in southwestern Pittsford has been disjoined from that forming the range on the west and was formerly at a relatively higher level. The schist east of the range occupies the downthrow side of a displacement.

If the indications of displacement offered by the topography may be accepted and the schist of the valley floor in southwestern Pittsford may be interpreted as just suggested, then it is possible without much difficulty to think of the calcareous rocks of the West Rutland valley as lying above the schist, as appears to be the case with similar rocks in the northern Taconic hills. The schist on the east side of the main range reaches down to such a low level that it is difficult to imagine that the marble is an inferior formation extending westward beneath it.

It might be argued, if the idea of faulting seems in any degree to be warranted, that purely topographic conditions could be discounted and that the valley rocks could be thought of as occupying the upthrow side of a displacement that dropped the schist now forming the Taconic range against a mass of older marble, and that it would be as easy to account for present apparent relations of the schist on the west side of the valley on such a view as it would on the assumption that the marble had been dropped from a higher level. But certain relations which have been observed farther north, in the western part of Brandon, not only strongly indicate that the marble is above the schist, but also that normal faulting has occurred between marble and schist so that marble in some places and schist in one place in particular now occupy an inferior level and seem to be on the downthrow side of a normal fault displacement.

In the Pine Hill mass of Rutland township the probability of a common age for schist and quartzite composing it seems very strong. The schist and quartzite formation along the western margin of the Green Mountain plateau, each of Pine Hill, with which the quartzite of Pine Hill joins in the southeastern part of Pittsford, shows quartzite interchanging with schist as in Pine Hill and in the eastern part of Brandon. It does not prove difficult, therefore, to find a reason for regarding the schist making up the present ridges to the west of the plateau, such as Pine Hill and that south of it in Clarendon, Tinmouth, Wallingford and Danby, both of which show no characters that are not understandable in such kind of terrigenous formation, as belonging to a formation which includes the massive quartzite. In Pine Hill and also in the ridge south of it there has probably been some differential movement within the terrigenous formation under pressure, because of the extensive development and massive character of the quartzite member. This may only be surmised, but certain relations between quartzite and schist in the northern part of the Taconic range suggest such a probability and such probability may be invoked to explain other relations within the Taconic range.

The fact of westward thrust at Pine Hill is reasonably clear, but the extent of the horizontal component of the thrust is not so apparent. It would not be difficult to offer explanation of the predominance of schist and the absence of any notable amount of quartzite in the ridge that separates the West Rutland and Center Rutland valleys, in contrast with conditions at Pine Hill, by assuming a considerable westward thrust at Pine Hill, with differential movement between quartzite and schist at Pine Hill, or

vertical and horizontal variations within the terrigenous formation.

If the schist of the West Rutland intermediate ridge is to be correlated with a formation older than the marble, then its relation to the marble of the West Rutland valley is probably one of thrust overlap. There may or may not have been some differential thrust movement between the schist of West Rutland intermediate ridge and the calcareous rocks of the Center Rutland valley prior to normal faulting between them.

If the rocks of the West Rutland valley are on the downthrow side of a normal fault displacement, as has been suggested, it may be that the marble is faulted with the schist on the east in the intermediate ridge as well as with that of the main ridge, but it does not appear that present relations require such interpretation. It seems likely that the schist of the intermediate ridge was thrust against the marble and that such movement was antecedent to a normal fault displacement between the rocks of the main range and the valley and that when such displacement occurred, the marble and schist east of the range were dropped together. The schist of the intermediate ridge was probably overlain by marble, and possibly other rocks, like those that now occur east and west of it. Such may be the significance of the patches of marble that apparently lie on the schist at the summit of the ridge north and south of the Pittsford line.

It is easy to imagine, when the region was under compression and thrusting occurred, that the amount of differential elevation and lateral movement of the subjacent terrigenous formation was different at different places. The present relations would depend upon the extent of thrust displacement, upon the relative positions of the rocks after later disturbance by normal faulting, and upon further modification by erosion. In places where the calcareous and associated dolomitic rocks now form the surface, the thrust displacements may be observed among them. In other places by reason of the relation brought about by thrusting and the particular way in which erosion has operated, the displacement is now to be observed between schist and dolomite or between schist and marble. In still other places we may assume that on account of erosion of all the dolomite or marble, or both, depending upon the primary relations of such rocks to the terrigenous formation, the present surface intersects thrust displacements within the terrigenous formation and that at numerous places within the Taconic range and where the schist is exposed in the intermediated ridges of the valley adjacent terrigenous rocks are in displaced relations to each other. The fact of displacement among adjacent terrigenous rocks is difficult to demonstrate, but the probability of such condition is strong in view of the prevalence of thrusting among rocks in other parts of the region. In certain places, apparently because of thrust overlap and possibly later normal faulting, patches of calcareous rocks are still preserved as detached areas within the terrigenous formation.

Hubbardton Township.

(Castleton topographic sheet.)

Location. Hubbardton lies south of Sudbury and is bounded on the east by Pittsford, on the south by Castleton, and on the west by Benson.

General description. The terrigenous rocks of Hubbardton township are in largest part the southward continuation of those of Sudbury, with such variations in lithological characters and areal distribution as one might expect in a formation probably composed originally of a variety of sediments and probably deformed by repeated crustal disturbances. The present rocks are slates, phyllites, schists, quartzite and other metamorphosed sediments. In Hubbardton the slates, which are sparingly found among the other kinds in Sudbury, are prominent at some places in the western part of the town.

In the northwestern part of Hubbardton, north of Roach Pond and east of the road running north to Hortonville, are patches of limestone, much altered, but still showing traces of organic remains. This limestone is lithologically similar to rock found west of Hortonville in the adjoining town of Benson, and farther north in Orwell and the western part of Sudbury, and which carries fossils of Trenton age. In Benson the Trenton rocks are associated with Chazy limestone.

The outcrops of the limstone in Hubbardton are interrupted at the present surface by areas of blackish phyllite or schist just as are the similar rocks in Benson, Orwell and Sudbury. This schist, apparently because it is associated with Ordovician limestones and apparently also because it is thought to have lithological similarity to other terrigenous rocks of the slate belt which are in association with rocks that carry graptolites, has been mapped as belonging to the Ordovician system.

The primary relation of the schist to the associated limestone north of Roach Pond is difficult to determine. Bedded structure is not distinct in either limestone or schist, but both are strongly sheared with easterly dip. The limestone forms narrow strips between bands of schist, runs out at the surface along the strike and is replaced by schist, which frequently is at a lower topographic level than the limestone along the strike of the latter. The relations are not so clear between these rocks as they apparently are in Orwell and Sudbury, but on the whole the impression gained is that the limestone lies on the schist and has been involved in the deformation of the latter. The limestone seems to have been folded with the schist, probably with some differential movement between the two, attended by strong shearing with obliteration of bedding in both.

Except for the scattered areas in the northwestern part of the township, as just described, the only other exposures in Hubbardton of rock which could be correlated with the limestone near Hortonville occur in the hilly land a mile and a half due east of Beebe Pond. The locality is just east of a road that first runs east from Beebe Pond and then bends southward to join another road that runs from Hubbardton church northeasterly and swings southward to East Hubbardton monument. About one-third of a mile north of the latter road, on a side hill, are ledges of limestone which resembles the Trenton rock of Sudbury and Orwell and that around Hortonville. No fossils were found and the structural relations of the limestone to the schist which everywhere surrounds it is nowhere shown by contact. The general relations, however, leave no doubt but that the rock is in place. The topographic position of this limestone seemed clearly to be against any idea that it might be an exposure of an extensive formation lying beneath the schist which surrounds it, because similar rock apparently does not occur at lower topographic levels roundabout where it should seemingly be exposed if the schist lay normally above an extensive formation of limestone. It appears rather to be an outlier and to have been preserved because of favorable structural position.

On published maps of the slate belt the hard rock in the eastern portion of Hubbardton has been shown as belonging to the so-called Berkshire Schist and is represented as joining with the schist in the western part of Pittsford. The western boundary of the schist in Hubbardton is definitely drawn, but field examination shows that any clearly-defined separation of the terrigenous rocks along the supposed boundary is impossible. Along this boundary the schist, which is called Ordovician in age, is represented as meeting a terrigenous formation of Lower Cambrian age. The difficulties of having the schist rest on the Ordovician marble on the east side of the Taconic range and on the Lower Cambrian terrigenous rocks on the west side, and of having the marble rest on dolomite in the Vermont valley and the schist on a Cambrian terrigenous formation west of the main range, are met by assuming that the part of the Berkshire Schist mass that meets the Cambrian terrigenous rocks on the west corresponds to the upper part of the marble formation of the east side of the range and that the Cambrian terrigenous rocks on which the schist is supposed to rest at the west represents the Cambrian dolomite of the Vermont valley. Differences of sedimentation during the Cambrian and the Ordovician, amounting to lateral variation sufficient to account for such apparent anomalies, are further assumed as probable.

On the western side of the main Taconic range some of the rocks west of the assumed boundary of the so-called Berkshire Schist are placed in the Lower Cambrian on the basis of fossils which have been reported at several places and others are assigned to this system by lithological correlation with those which yielded fossils. Middle and Upper Cambrian rocks are not known and the schist is regarded as resting unconformably upon the Lower Cambrian formation. Thrusting and faulting are not ruled out, but the inclination has been to explain structure in other ways, where displacement may not be positively shown.

The accounts of the region which attempt to show the existence of a formation of Ordovician age forming the present surface of the Taconic range are obliged to proceed on certain assumptions founded on apparent field relations which may perhaps be interpreted in different ways. It is seen that the assignment of the schist of the Taconic range to the Ordovician system presents difficulties of satisfactory correlation with other rocks east and west of the range which are supposed to be of similar general age. The idea of variations in contemporaneous sediments may probably be invoked to explain certain relations within the region; but it seems doubtful if it may be applied as has been done in correlating the Berkshire Schist with the marble formation. Calcareous rocks, such as those composing the marble formation east of the Taconic range, do not occur along the western boundary of the so-called Berkshire Schist, as it seems they should do if the marble formation really dips beneath the schist on the east side of the range. No field relations between the Berkshire Schist and the terrigenous rocks of supposedly Lower Cambrian age which the schist is represented as meeting on the west of the Taconic range justify the notions that a displacement has dropped the schist and has, therefore, carried the marble down and that on account of such displacement there has been opportunity for schist and marble to be eroded from the "Cambrian" rocks of the slate belt subsequent to faulting. To keep the schist on the marble on the east side of the Taconic range and at the same time preserve the conception of an unconformity in the Taconic region between the Lower Cambrian rocks and the Berkshire Schist, in one case and between the Lower Cambrian terrigenous rocks and certain Ordovician limestones in another case requires a stretch of the imagination, although it might be contended that the effort to imagine such relations would not be greater than that required for other interpretations of the structure.

The calcareous rocks of known Ordovician age which are now present west of the Taconic range in various parts of the slate belt have apparently not been exposed by erosion of an extensive formation of overlying terrigenous rocks, although it is possible that in some cases limestones have been preserved by having been involved in the folding or shearing of underlying terrigenous rocks.

It is not argued that there are no terrigenous rocks of Ordovician age in the Taconic region, but it is suggested that a number of field relations make it possible to imagine that most of the so-called Berkshire Schist does not belong to that system. Even the terrigenous rocks in the western part of Hubbardton, which are distinguished on maps of the region from large areas of supposedly Lower Cambrian rocks, have apparently not been shown by fossils to belong in the Ordovician system, as represented, although they are thought to resemble rocks elsewhere in the slate belt which are associated with rocks carrying graptolites. If the schist actually lies, as it seems to, beneath the calcareous rocks in western Hubbardton, in the absence of fossils it may be questioned if much of such schist is of Ordovician age.

The lack of sharp separation between Berkshire Schist and so-called Lower Cambrian rocks is apparent along many surface sections from east to west in the town of Hubbardton and in townships to the north and south. The Lower Cambrian formation shows many variations throughout the areas which have been mapped as occupied by it. Slate, phyllite and schist, each showing in many places segregations of quartz, which probably represents sandy beds in muddy sediments of various kinds, and massive quartzite, pass into one another at the present surface. There seems to be no particular order in the distribution of the rocks, except that in general the finer-textured slates and phyllites seem more prominent at the west and the coarser varieties at the east. Phyllitic rocks similar except for slightly greater crystallinity to many rocks of the slate belt occur east of the supposed western boundary of the Berkshire Schist and are associated with other rocks which it did not seem difficult to correlate in their lithological features with similar rocks in areas farther west.

Over the eastern part of Hubbardton there seemed indeed to be an intermingling at the present surface of phyllites, schist and quartzite, such as has been described for the Taconic hills in Sudbury and the western part of Brandon. Areas of pure massive quartzite occur in Hubbardton as in the western part of Brandon, but a more common variety of coarse rock is an impure schist or graywacke quartzite which is frequently marked by segregations of quartz apparently resulting from sandy layers or lenses. Quartz segregations are, however, frequent in the finer-textured rocks of the Taconic region.

At Zion Hill, two-thirds of a mile southwest of East Hubbardton monument, beds of massive quartzite, in all perhaps 60 to 75 feet thick, lie above green and purple slates or phyllites. The hill has abrupt cliffs on the east, north and west. The beds form a small synclinal fold. East of the hill similar beds seem to have an anticlinal arrangement. The abrupt northern side of the hill faces a gentle slope extending from the base northward to the East Hubbardton road. The massive quartizite may have thrust displacement relation to the rocks that surround it. While the structure is not clear, the quartzite is regarded as an integral part of the general terrigenous formation. Similar quartzite occurs at Barker Hill two miles to the south, in Castleton, on meridians closely approximating those occupied by the quartzite of Zion Hill.

The heavier quartzite members of the terrigenous formation must have resisted deformation much more than the finer sediments. The latter as they are now shown in the quarries of the slate belt may be seen to have been jammed into close folds, overturned and strongly sheared. If one makes no age distinction among the terrigenous rocks of Hubbardton and other areas in the Taconic region as well—at least, for the areas that have been mapped as Berkshire Schist and Lower Cambrian—the surface rocks over a large area seem to compose a formation that is homogenous in its heterogeneity, consisting of the metamorphic derivatives of many varieties of sedimentary rocks. These may be thought of as having behaved under the compression, which their structure shows they at one time experienced, more or less according to the features of their primary structure. Under erosion these rocks also behaved according to their primary natures, but secondary structural features were controlling factors as well.

It is evident from a study of these rocks in the field that they have suffered extensive denudation. The only suggestion which we now have, from the areas over which they now chiefly form the surface, of what may formerly have lain above them, is apparently found in the scattered remnants of limestone that appears to be of Ordovician age, and possibly in certain terrigenous rocks whose actual surface extent is very uncertain.

If one may generalize from the structure shown by the muddy rocks of the slate belt it appears that in general the effect of compression was to produce numerous minor folds, but it seems probable that the more fully competent character of much of the terrigenous rock to resist compression would have introduced dislocations of the nature of thrusts and that there would have been much irregularity on account of primary irregular distribution of the different kinds of terrigenous rocks. But one finds it difficult or impossible to locate thrust contacts with certainty in this much dissected region.

Castleton Township.

(Castleton topographic sheet.)

Location. Castleton lies south of Hubbardton and between Fair Haven on the west and Ira on the east. It is bounded on the south by Poultney.

General description. The same general assemblage of ter-

rigenous rocks that forms the surface over most of Hubbardton township makes up the hard rock surface in Castleton. In this township fossils have been reported from only a few places and correlation of the rocks has been, therefore, almost wholly on the basis of lithological resemblances to other rocks of the region which have yielded fossils or whose structural relationships have been interpreted as indicative of their age. The Berkshire Schist is represented on maps of the region as extending south from Hubbardton into the eastern part of Castleton, where it is shown as joining eastward with the schist of Ira, which joins with that of West Rutland. As in Hubbardton the schist in Castleton is represented as meeting along a fairly definite boundary a formation of terrigenous rocks which are assigned to the Lower Cambrian system.

A relatively narrow band of slates has been described and mapped as belonging to the Ordovician system and as extending in the midst of the Lower Cambrian rocks in a general north-south direction through West Castleton, west of Lake Bomoseen. From some of the rocks included in this belt, graptolites have been reported and the forms are thought to leave no doubt as to their Ordovician age. The structural relation between the rocks that are called Ordovician and those which are called Cambrian is not clear. As is the case all through the slate belt, the rocks have been much disturbed. From the structure shown in certain ledges the "Ordovician" slate is believed to have synclinal structure and the Cambrian rocks east of it are described as probably being overturned to the west, or faulted.

The various other terrigenous rocks of Castleton show no more regularity in distribution than do those of Hubbardton and field inspection shows that the various kinds pass into one another at the present surface. They present puzzling relationships. The boundary between Berkshire Schist and Cambrian rocks seems no more clearly defined than in Hubbardton.

While the rocks which have been called Cambrian are largely terrigenous in character it should be noted that in Castleton and in other parts of the slate belt there are within the terrigenous formation beds of calcareous rock which carry Lower Cambrian fossils. The Lower Cambrian terrigenous rocks are slates, phyllites, schists and quartzite, but sometimes associated with quartzite are quartz conglomerates and not very different conglomeratic rocks are also found associated with quartzite in areas mapped as Berkshire Schist.

Because of their heterogeneity and present arrangement any detailed description of the distribution of the various rocks of Castleton would be difficult, but some special features should be noted.

Slates are prominent in the western half of the town, but are more or less intimately associated with other kinds of rock. At the east the rocks are prevailingly coarser and less pure and are now represented by phyllites, schists and less frequently by quartzite. A quartzite like that making up Zion Hill in Hubbardton occurs two miles south of it at Barker Hill in Castleton. The two may be parts of a once continuous mass or each may represent a lens-like mass of quartzite within other sediments.

A mile east of Lake Bomoseen, just south of the Hubbardton line, is a prominent scarp known as Wallace Ledge. The face of the scarp shows a considerable thickness of greenish slate, or phyllite, capped by a bed of quartzite perhaps 25 feet thick. Overlying the quartzite is phyllite similar to that beneath it. From the road west of Sucker Brook the quartzite layer was seen to be much folded.

The conditions at Zion Hill and Wallace Ledge seem to give some clue as to the primary arrangement of some of these terrigenous rocks. More or less sandy layers or lenses were interstratified with muddy rocks and apparently the thickness of the sandy rock varied at different places. It seems likely that these sandy layers underwent a certain amount of induration prior to folding of the various rocks and when brought under compression were not easily deformed and probably in many cases were fractured with displacement. The quarry hole at Cedar Point on the west shore of Lake Bomoseen shows an overturned syncline with the axial plane nearly flat, dipping slightly to the east. It is easy to imagine a rock mass riding forward along a thrust plane on the overturned limb of such a fold.

On the meridan of Wallace Ledge and two miles south of it, at Bull Hill, the green and purple slates are quarried.

Bird Mountain. In the southeastern part of the township, but partly in the adjoining towns of Ira and Poultney, is a singular pile known as Bird Mountain. In its outlines it has same resemblance to Zion Hill in Hubbardton except that it is larger and has a high scarp facing to the south instead of to the north and has a northerly pitch. A coarse talus lies at the bases of the cliffs that bound the mountain on the east, south and west and sloping away from the talus piles on the three sides mentioned is boulder drift which conceals the underlying rock. Along the road west of Bird Mountain are green and purple phyllites quite similar to rocks found farther west and similar rocks peak through the drift along the road east of the mountain.

The rocks of the mountain were inspected on the southern face above the talus slope and on the eastern side and the summit. They consist of fine-grained conglomerates, quartzites and sericitic phyllite and are interbedded. Judging from the rocks seen in the southern face of the mountain and on its summit the conglomerate is not extraordinarily abundant. From its interbedded character it is best interpreted as intraformational. Petrographic analyses of the conglomerate have shown in addition to quartz

pebbles others of crystalline limestone and some of quartzite with calcareous cement, sources for which are problematical.

Rocks similar to those at Bird Mountain occur about two miles south by west of the mountain in the town of Poultney and will be briefly mentioned in the description of that township.

The presence of a conglomerate like that of Bird Mountain and the areas farther south suggests erosion of a land surface not very remote from the place of its deposition, but it does not necessarily indicate any great hiatus. Conglomeratic rocks, usually less extensively developed, are found at other places in the Taconic region, sometimes closely associated with other rocks carrying Cambrian fossils. In the older rocks now found at the surface in various parts of western Vermont there is strong indication that a variety of conditions prevailed during their deposition. There seems to have existed in Lower Cambrian time a shallow trough bordered by a land mass with somewhat irregular coastline. In a part of this trough accumulated the material now represented by the Sandrock series of northwestern Vermont. Along the border of the land at different places the conditions were often favorable for the formation of thick masses of quartz sand with or without subordinate inclusions of impure muds. At other places rivers apparently built out deltas of diversified sediments which were spread out not far from the land in the shallow sea. Oscillations were not infrequent. For the most part terrigenous sedimentation prevailed in the delta accumulations, but sometimes calcareous beds were formed during encroachment of the sea and apparently at a time of greater submergence of the terrigenous deposits of the delta areas, dolomitic rocks, like those which were laid down in parts of the sea into which rivers did not carry much land sediment, were deposited, to some extent at least, on the earlier delta deposits. All parts of the floor of the sea in which these varied contemporaneous deposits were formed apparently oscillated from time to time and in many places the sediments were exposed to the air and more or less oxidized. Many physical features of the rocks point to shallow water conditions during their formation and to periodic oscillation of the sea bottom. In the deltas, probably owing to elevation landward, coarser deposits were carried by streams away from shore and distributed on the delta surface.

The field relations of the rocks of Bird Mountain make it difficult to separate them from the other terrigenous rocks with which they are associated. All seem to be part and parcel of the same formation. Although the coarser sediments of Bird Mountain and other localities probably mean a time of elevation and erosion, in a general sense they were probably contemporaneous with the other rocks of the region. The ideas just presented are contrary to the views of other students. The idea has been entertained that the Bird Mountain rocks indicate a greater hiatus than that just suggested and represent a somewhat extensive formation, now largely eroded. The rocks have been assigned to different systems; first, to the Upper Silurian (Silurian), and later to the upper part of the Ordovician. There are good reasons for thinking that rocks like those of Bird Mountain were once somewhat more extensive than at present, but it does not seem likely that they were ever widespread. It seems reasonable to regard them as somewhat local developments of coarse rocks in a region which at other places shows similar rocks as normal variations in the process of accumulation of terrigenous sediments in a shallow sea and in which both the sea bottom and the adjacent land underwent oscillations of level. Even if a group of sediments like those of Bird Mountain marked a considerable time interval separating portions of one system it seems as though it should be more widespread than it is today; although the probability that the hiatus in such a case would not everywhere be represented by conglomerates and corse sandstones must be recognized.

By implication the validity of the term, Berkshire Schist, as the name of a formation distinct from various other rocks of the region has been questioned in the preceding pages and the suggestion has been offered that most of the rocks found in areas that have been mapped as Berkshire Schist are possibly the time equivalents in a broad sense of rocks found in areas mapped as Lower Cambrian within the slate belt and of rocks found in the western marginal portions of the Green Mountain plateau and in the intermediate schist ridges of the Vermont valley west and south of Rutland. This idea takes into account probable primary variations within a formation of probably contemporaneous and diversified sediments as well as characters that would appear after regional metamorphism of a mass of rocks showing such original differences. Little direct evidence is available for the age of most of the rocks in question. Recognition has been given by other students to the fact that within areas mapped as Berkshire Schist rocks occur which are similar to some which are found in nearby areas that are mapped as Lower Cambrian, but the further notion has been that these are instances of parallel development and not indications of kinship. The possibility of such conditions must be admitted; but in the writer's view the field relations do not seem to support the interpretations of the relations of the schist and associated rocks that have been offered and bear away from the commonly held idea that the schist is of Ordovician age.

Ira Township.

(Castleton topographic sheet.)

Location. This township is irregular in shape. Its wedge-shaped northern portion touches the southeastern part of Hubbardton and the southwestern part of Pittsford. On the west it is bounded by parts of the townships of Castleton, Poultney and Middletown, and on the east by parts of West Rutland and Clarendon. On the south it borders a part of Tinmouth township.

General description. The surface rock in Ira, except for a very small area of altered limestone which will be described beyond, is of terrigenous character and has been mapped as part of the Berkshire Schist. Outcrops were examined along a section crossing the township two miles north of Castleton River, along the road east of Bird Mountain, and along the roads and on the hillsides north, west and south of the village of Ira.

North of Castleton River, a mile south of Ransomvale, a road runs east from the main Castleton-East Hubbardton road and crosses the range through a saddle to the West Rutland valley. The rock which outcrops frequently in the clearing along this road on top of the range is a crupled impure schist which often carries segregations of quartz. On the western slope, in the bottoms of brook gulleys in the drift, outcrops of greenish schist were noted. This rock closely resembles the phyllite or schist along the road east of Bird Mountain to the south of Castleton River.

The terrigenous rocks north, west and south of the village of Ira show the usual types found within the Taconic range and the intermediate ridges east of it. They consist of impure quartzitic schists, rusty sericitic schists and black schists and, as a whole, give an assemblage which in comparison with the surrounding region shows no distinctive features.

The limestone at Day's quarry. A little more than a mile northwest of the village of Ira, on the farm of D. D. Day, is a small patch of altered limestone which has been quarried for lime. The area occupied by this rock is probably not more than 400 feet wide and 1,000 feet long. The limestone is surrounded by the characteristic terrigenous rocks of the region.

Just north of the quarry the weathered surface of the limestone shows numerous sections of gastropod shells which are not well enough preserved for positive identification, but which strongly suggest some form of *Maclurea.*

Limestone and schist are close together in some places, but only one contact was seen. On the east side of the quarry, near the kiln, the marble lies against the schist and above it. It could not be determined whether the relation between marble and schist is primary or secondary. It did not seem probable that the marble is an inclusion in the schist. If this were the case, seemingly there should be more frequent occurrences. That the marble has been exposed by erosion of part of a conformable mass of overlying schist seemed equally improbable, for such a view would imply a somewhat extensive mass of marble overlain by schist, and if such were the primary condition it would seem that other portions of the marble should have been exposed by erosion at places not very distant.

The marble at Day's quarry is a graphitic rock. It is singularly isolated from any other exposures of similar marble. It occupies a sort of pocket in the terrigenous formation. The contact shown near the kiln may not be a normal one, but it offers direct evidence that the marble rests on the schist. At no place was the latter found lying above the marble. In view of the small exposure and isolation it seems likely that the explanation of its preservation is to be found in the deformational changes which the region has experienced.

Poultney, Middletown, Tinmouth, Wells, Pawlet and Danby Townships.

(Castleton and Pawlet topographic sheets.)

General description. The townships mentioned in the heading make up the southwestern portion of Rutland County. Their relative positions will be mentioned as the special or general geologic features of each is described. The rocks in these townships were examined chiefly along the roads that traverse them and to some extent in the woods and open fields.

Poultney. This town lies south of Castleton. The hard rocks forming its surface have been described and mapped as belonging partly to the Lower Cambrian terrane and partly to the Ordovician system. Those classed with the Ordovician include the so-called Berkshire Schist of the eastern part, which is regarded as the southward continuation of the same formation in Castleton, and some other terrigenous rocks of the western part from which at one or two places graptolites have been reported. The so-called Lower Cambrian terrigenous rocks border the schist on the west and surround the other "Ordovician" rocks.

The so-called Ordovician terrigenous rocks in the western part of the town seem indeed to have in many cases lithological characters that serve to distinguish them from the purple and green slates and other types that are called Lower Cambrian, but in the Taconic region it is hardly possible, in most if not in all cases, to say what the nature of the boundary now is between rocks that are thought to be of one age and those that are considered to belong to a different system. The boundaries of the different rocks have clearly been drawn in very large measure on the basis of lithological features. But as the writer has elsewhere shown the field relations among terrigenous rocks similar to those of the townships so far discussed are in many places often of such character that it is impossible, in the absence of the direct evidence afforded by fossils, to make any separation with respect to their age on the basis of lithology. Furthermore, different kinds of rocks often show such intermingling and such kind of intermingling at the present surface that they appear to belong to one system rather than to two.

The Berkshire Schist in Poultney seems to be no more sharply defined from the so-called Lower Cambrian than it is in Castleton and Hubbardton.

In the northeastern part of Poultney are a number of high hills showing prominent scarps on the east and in several places. The rocks of these hills are quartzite with interbedded conglomerate and schist. They seem to be the southward extension of the rocks of Bird Mountain, from which they are separated at the present surface, but with which they may once have been continuous. These hills are surrounded by green or purple phyllites which frequently carry thin beds of quartzite. Northeast of Hampshire Hollow the structure of the heavy quartzite and associated rocks suggests that they are all a part of the same formation and that they have been deformed together. Southwestward the quartzite and associated conglomerate disappear at the present surface and their places are taken by the schist. Old Knob, a hill lying between Fennell and Hampshire Hollows, is a mass of green and purple phyllite, but southwest of the hill, east of Fennell Hollow road, is black schist which does not seem to differ from rock which has been mapped for other areas as of different age. West of Fennell Hollow is schist, much of which is black, and which has been mapped as Lower Cambrian. East of Old Knob, at the northern end of Hampshire Hollow, the surface rock east of the road is often a coarse graywacke schist, which has been mapped as Berkshire Schist. Irregular sections across the strike of the rocks north of East Poultney give a sequence from blackish schists through green or purple varieties to coarse sericitic graywackes and there are no clearly marked boundaries among them.

The only calcareous rocks which were seen in Poultney were found one mile south of Spaulding Hill, south of the Moss Hollow road. An exposure of sheared dolomitic limestone, hardly more than thirty feet square, seemed to be in place, but there is much uncertainty about it.

Middletown. The rocks of Middletown offer no distinctive features. They have been mapped as belonging to the Berkshire Schist formation. So far as examined along the main east-west road from Middletown Spring to Pawlet they are in general like the rocks called Berkshire Schist in the surrounding townships and show very similar variations.

Tinmouth. In the township of Tinmouth, which bounds part of Middletown and part of Wells on the east, were found two detached areas of altered limestone surrounded by the schist formation. One of these lies about a mile south of the Ira township line and one-third of a mile east of the Middletown boundary, north of the road from Middletown Springs to Tinmouth village. The rock is a sheared limestone, much like that which occurs in many places in the northern part of the Taconic range in Sudbury. The limestone forms low-lying ledges of varying but always small dimensions, surrounded by drift, and would easily pass unnoticed except in systematic search. The rock is in place without any doubt and the area occupied by its outcrops is perhaps several acres in extent. The conditions are such as to suggest that similar limestone may underlie the drift in other places within the Taconic region. Probably the actual area covered by the limestone at this locality is somewhat larger than that over which its outcrops now appear. The rock has been altered almost to the condition of a marble. It is apparently everywhere surrounded by the schist formation. The nearest outcrops of similar rock are nearly a mile to the east along the western side of Tinmouth valley, where at several places the so-called marble appears to lie above the schist, as previously described by the writer.

Another isolated area of altered limestone was found about five miles southwest of that just described. It lies west of the mountain called The Purchase, and one-third of a mile north of the Danby line. The limestone at this locality, like that on the Middletown Springs-Tinmouth road just described, is surrounded by drift and its outcrops are intermingled with the surface material. The actual area and boundaries of the calcareous rock could not be determined. A brook south of the principal outcrops of the limestone cuts deeply into the drift without exposing the hard rock. The limestone forms numerous outcrops. It is certain that it is not a part of the drift. The nearest outcrops of a similar limestone occur three miles to the east on the western side of Tinmouth valley.

Wells. This township lies south of Poultney along the New York border and is bounded on the east by Tinmouth and on the south by Pawlet.

Most of the hard rock surface has been mapped as belonging to the Berkshire Schist. West of the schist is a band of slates which has been represented as part of the Lower Cambrian and west of this band, along the state border, a strip is shown which is regarded as made up of Ordovician terrigenous rocks like those intermingled with the purple and green slates of other parts of the slate belt.

The eastern and central portions of the township have a rugged surface which joins eastward with that of Middletown and Tinmouth. This more rugged portion is bounded on the west by a series of prominent scarps which lie approximately along the same north-south line. This scarp topography continues southward into Pawlet in the steep western faces of Simonds, Cleveland and Burt Hills, and northward is represented by a steep scarp on the west side of St. Catherine Mountain in Poultney. Lake St. Catherine and its southward extension, known as Little Pond, lie west of this line of scarps.

The fact was not mentioned in the descriptions of Hubbardton and Castleton, but a broken line of scarps extends from Sudbury on the east side of Keeler Pond in Hubbardton and southward past Beebe Pond to Lake Bomoseen in Castleton. North of Castleton the scarps are interrupted by gentler slopes and are always of lower altitude than those at the south, east of Lake St. Catherine. In the topography and in the arrangement of these water bodies there are strong suggestions of displacement along a zone extending from the hills in Sudbury into Pawlet and that the different ponds and lakes lie in structural basins. There is indication of faulting also on the southwest shore of Lake Bomoseen and in the hilly land west and northwest of the lake.

There are in fact at many places in the Taconic region scarps bounding the higher elevations which suggest displacement. Some of these scarps face to the east, others to the west, while others run from east to west across the strike of the rocks. Cliffs and scarps contribute very appreciably to the topographic outlines of the Taconic region.

In most cases where scarps suggest old fault lines or where faulting may be suspected for other reasons, the fact of displacement cannot be demonstrated because of the similarity or nature of the rocks that lie in juxtaposition. If lines were drawn in on a map of this region to represent all the probable displacements within the mountains and their foothills they would undoubtedly be viewed with suspicion, but an inspection of the territory itself would probably be convincing to many observers.

At the northern end of the range, in southwestern Brandon and in Sudbury and Orwell, as has elsewhere been explained, faulting along and across the strike may be shown to have been a frequent occurrence. In this part of the range the fact of displacement may be more readily appreciated because of lithological differences between the rocks involved. On both the east and the west sides of the hills in Sudbury the limestone and schist often clearly lie in faulted relation to each other. In some places it may be observed that the calcareous rock lies above the schist and that on the downthrow side of a displacement, erosion has removed the calcareous rock at some places, thus giving limestone at one place and schist at another lying against the schist of the upthrow side. The calcareous rock has been partially or wholly eroded from the schist of the upthrow side. Moreover, a study of surface sections from east to west across the northern end of the range seems to show that fault lines occur within the schist of the range and that some of the scarp and basin topography of the present surface are primarily due to ancient displacements.

It seems very probable that the scarp topography that has been described above as extending from Sudbury to Pawlet along the chain of ponds that were mentioned, represents a prominent zone of fracture in a region marked by subordinate displacements at many places. That the displacements which seem to have occurred in the Taconic region all belong to the same episode of disturbance is not certain. Some of them may have occurred at the time when the structural outlines of the Vermont valley and Champlain lowland were laid down and others may have occurred later.

Pawlet. The rocks of Pawlet are the southward continuation of those of Wells. In Pawlet, and in the township of Rupert south of it, the Berkshire Schist of the eastern part has been represented as contiguous at the present surface with other Ordovician terrigenous rocks of the western part, and in Rupert certain grits which have been described as carrying fragments of various rocks and as associated at places with graptolite shales are called Ordovician and further described as showing transition into the Berkshire Schist.

Near the southern boundary of Pawlet, west of the road from Pawlet village to Dorset village, about two and a half miles south of the former, and also a little farther north on the east side of the road, are patches of altered limestone intermingled with and surrounded by the schist formation. The calcareous rock at some places can be seen to have been jammed into small, closely-compressed folds and to have been strongly sheared. The limestone has general resemblance to that which has been described in preceding pages as occuring as probable outliers within the schist. In Pawlet the primary relation of limestone to schist is obscure. The two rocks were apparently simultaneously involved in some deformation due to compression.

Danby. Danby township lies east of Pawlet. Its western half includes a part of the Taconic range. In the eastern part the northward extension of Tinmouth valley separates the main range from Danby Hill, which is the northward extension of the Clarendon-Tinmouth ridge which separates the Clarendon River-Tinmouth valley from that of Otter Creek.

The Clarendon River-Tinmouth valley, including its southward extension into Danby township, seems to have a structure like that described for the West Rutland valley. It appears to occupy a downthrow position with respect to the main range on the west. It and the ridge that bounds it on the east are subordinate topographic features of the major or Vermont valley.

The subordinate ridge east of Tinmouth valley is composed chiefly of schist and massive quartzite like that which makes up Pine Hill north of Rutland and the schist and quartzite have much the same relations to one another in the Danby-Clarendon ridge that they do in Pine Hill. They seem to be parts of the same formation.

East and west of Danby Hill are interbedded dolomitic and quartzitic rocks like those found so widely distributed throughout the Vermont valley.

Along or near the road on the west side of Tinmouth valley, in Danby and northward in Tinmouth and Clarendon, are intermittent outcrops of marble which along some meridians on which they occur are interrupted by exposures of schist. In some places the marble gives the distinct impression of lying above the schist.

On the ridge intermediate between Tinmouth valley and the main Otter Creek valley the quartzite-schist formation is apparently overlain by patches of marbly limestone. Some of these occur in Danby and others just north of the Danby line in Tinmouth and Wallingford.

The southern part of Danby township includes the northern slopes of Dorset Mountain, on which are various exposures of marble, some of which are quarried. An east-west fault zone bounds Dorset Mountain on the north. The displacements which separate Dorset Mountain and Danby Hill apparently belong to the episode of deformation during which were formed the structural outlines of the Vermont valley, and were contemporaneous with those which "dropped" the rocks of Tinmouth and West Rutland valleys.

A small area of "marble" has been described as occurring within the main range in the western part of Danby township, to the west of Dutch Hill, between it and Harrington Hill, but this was not found by the writer.

Dutch Hill and Mount Hoag in the western part of the town show scarps like those in the hills to the north and south.

The terrigenous rocks in the western part of Danby are like those in other parts of the Taconic range and the schistose types do not differ from those found associated with the quartzite in the intermediate ridge east of Tinmouth valley.

BENNINGTON COUNTY.

Dorset Township.

(Pawlet and Equinox topographic sheets.)

Location. Dorset lies south of Danby. It is bounded on the west by Rupert, on the south by Manchester, and on the east by Peru.

General description. The main portion of the Dorset Mountain mass lies in this township. The mountain forms a physiographic outlier of the Taconic range and juts so far east across the Vermont valley that its eastern slopes are separated by the distance of a mile or less from the western edge of the Green Mountain plateau. Westward it joins with Woodlawn Mountain in Danby and Pawlet.

North of Dorset Mountain the main valley lying between the Taconic range on the west and the plateau on the east is wide and it broadens gradually northward until it merges with the Champlain lowland at the latitude of Brandon. But north of Dorset Mountain the surface of the main valley is broken by intermediate ridges, which have been frequently mentioned in preceding pages. South of the mountain the main valley as it extends north from Manchester makes a deep embayment in the Taconic range along the West Branch of the Batten Kill. The surface of the valley south of Dorset Mountain is not broken by any ridges like those north of it and presents only minor irregularities, such as characterize the valley throughout its extent.

Dorset Mountain, besides presenting an interesting spectacle, gives the critical student an impression of holding some special significance in the geology of the region.

The higher portions of Dorset Mountain are composed of schistose rocks much like those which make up the Taconic range everywhere. Around the slopes of the mountain on the north, east and south is a fringe of marble. The schist of the mountain has been discussed in different accounts of the region as lying normally above the marble and the latter has been described as exposed everywhere that it now occurs around the slopes of the mountain, in the gulleys that dissect it and in the valleys roundabout by the erosion of a covering of schist like that which now forms the summit of the mountain.

The floor of the valley east of the mountain is very irregular and the surface rock belongs to the formation of interbedded dolomite and quartzite of the Cambrian series. These rocks extend variable distances up the east slope of the Dorset Mountain mass. Below the summits known as Netop Mountain, Dorset Hill and Green Peak the topography offers strong suggestion of a north-south fault zone and a road along the mountain side below these eminences traverses a sloping bench whose surface in the higher western portion is formed of marble with associated dolomite and in the eastern portion is made up of the dolomitic rocks of the Cambrian. At the latitude of North Dorset the road just mentioned turns abruptly east a little way south of what appears to be an east-west fracture along which the rocks that form the bench have been "dropped" against the northeastern part of the Dorset Peak mass.

On the east of Green Peak there is a vertical repetition of the marble which suggests displacements and a tier-like arrangement of the marble may also be noted west of Owls Head, and also north and northeast of Dorset Peak. Contacts of marble and schist were not found and definite indications that the marble passes beneath the schist seem to be lacking, so far as the writer's observations have gone.

The Freedley quarry at Dorset Hill is one of several openings along the same general contour on the east side of Dorset Mountain. The older openings, now abandoned, lie south of the Freedley quarry. Above the old quarries are steep ledges of schist from which have tumbled huge bowlders, each weighing many tons, which lie scattered about on the rather steep slope at the bases of these ledges. Although careful search was made, no contact of marble and schist was found. The marble at Freedley's and at the other quarries south of it usually lies nearly flat, or has westerly dip, and from this structure would be interpreted as passing beneath the schist which caps Dorset Hill; but it seems possible to interpret the relation between schist and marble in another way, in spite of the suggestion giving by the westerly dip of the marble.

The floor of the valley along the West Branch of the Batten Kill, south of the Dorset Mountain mass, shows numerous outcrops of marble or marbly limestone both to the north and south of the road from South Dorset to East Rupert and Pawlet, but the commercial marble occurs around South Dorset not far from the western margin of the interbedded rocks of the Cambrian that form the surface of the main valley and the calcareous rocks west of South Dorset, although they probably belong to the marble formation, are less altered than are the rocks near South Dorset. The sequence from east to west in these rocks is much like that shown in Brandon township.

Outcrops of calcareous rocks occur on the lower slopes of the hills that form the northward extension of the Bear Mountain mass, but these give place farther up slope to the phyllite and schist characteristic of the Taconic range. Patches of calcareous rock of indeterminable dimensions are intermingled with schist about a mile and a half northeast of East Rupert along the road that runs west of Dorset Mountain from East Rupert to Danby Four Corners. The rock is somewhat marbly and carries many patches of gray-weathering dolomite. It strongly resembles the marbly rocks found north of the Sudbury hills. It apparently occurs as a detached area surrounded by schist, although it may possibly join at the present hard rock surface with similar rock to the east of East Rupert along the approach to Kirby Hollow.

Around East Rupert and on the hill slopes south of Dorset village there are no contacts to show that the calcareous rock passes beneath the schist formation. While the drift hides contacts, the impression gained from the manner in which the calcareous rock gives place to schist is that the calcareous rock lies on the schist. The apparent absence of the calcareous rock northwest of East Rupert, except for small patches in the southern part of Pawlet township which have been described, seems to have the same meaning, namely, that the position of the schist is beneath the other rock and that the latter has been eroded from the schist northwest of East Rupert. The schist, in fact, outcrops close by the road in many places between East Rupert and Pawlet. It seems that if the schist were superior to the marble formation, the latter should have been exposed and be now visible in more places than it is along this valley.

Marbly limestone occurs on the southern slopes of the spur that bounds Dorset Hollow on the west, but elsewhere in Dorset Hollow calcareous rock was not found, except in a few outcrops on the northern slope of the Owls Head spur and in an obscure and isolated "quarry" near the foot of the trail that leads from the northern end of Dorset Hollow to the summit of Dorset Peak. The slopes of Dorset Hollow are very heavily drift covered. The drift may conceal the limestone in Dorset Hollow.

The calcareous rocks northwest of Dorset village along the surface of the valley and on the slopes adjacent show no regularity of structure, but dip in all directions, and nowhere within the circumscribing schist border of the valley around Dorset, except as schist is intermingled with the limestone around East Rupert have any outcrops of schist been found. This relation has been interpreted to mean that the calcareous rock dips beneath the schist at the border and that the schist has been eroded from the limestone of the valley, but the relations seem to admit of an alternative interpretation which is favored by the field relations that have been mentioned.

Concerning the terrigenous rocks of Dorset township as a whole it may simply be noted that they possess the general characters that have been described for the terrigenous rocks in the Taconic range from Sudbury southward and seem to show no distinctive variations.

Rupert Township.

(Pawlet and Equinox topographic sheets.)

General description. Rupert lies west of Dorset and between Pawlet on the north and Sandgate on the south. The rocks were examined only along the valley of the Mettawee and the adjacent slopes in the northeastern part of the township, and in the hollows bounding Shatterack Mountain in the southwestern part.

Except for a patch of altered limestone belonging to a small area that lies chiefly in the southern part of Pawlet and which has been described, the rocks of Rupert on the hills and in the hollows within the areas examined are schists and related rocks like those of the Taconic range in general. In the hollows, so far as seen, erosion has exposed no calcareous rock passing beneath the schist formation.

Manchester and Sandgate.

(Equinox topographic sheet.)

Location. Manchester lies south of Dorset, between Sandgate on the west and Winhall on the east. It is bounded on the south by Sunderland.

General description. A part of the western edge of the Green Mountain plateau crosses the southeastern portion of the

township; Equinox Mountain with the highest peak of the Taconic range occupies the western portion, between the two is the Vermont valley.

The western slope of the plateau is formed of quartzite. West of the quartzite is a broad band of dolomitic rocks which make up most of the floor of the valley in Manchester. West of the dolomite series the outcropping rock on the piedmont slopes and in the foothills of Equinox Mountain and over a part of the western side of the valley is usually marble so that there appears to be a band of marble extending along the western side of the valley, joining at the north with the marble in the southern part of Dorset.

The marble reaches different altitudes on the eastern slope of Equinox Mountain. At the northern end of the mountain, between it and the mass of Bear Mountain is a col through which passes the road from Manchester to Beartown in Sandgate township. Calcareous rock belonging to the marble formation outcrops in this saddle at the 2,500 feet contour and was followed for a third of a mile along the trail that leads from the Beartown road to the summit of Equinox. Contact between marble and schist was not seen.

Patches of calcareous rock, apparently also belonging to the marble formation, were seen south and west of Beartown village, but the extent of the marble in the hollow around Beartown is very uncertain.

A conspicuous ledge of sheared marbly limestone southwest of Manchester village forms what is locally known as Table Rock. The ledge has a precipitous scarp on the southwest and is separated by a deep ravine, known as Cook Hollow, from a wall of schist which makes the west side of the hollow. The sides of this ravine are much steeper than the topographic map shows. The general relations offer suggestion that marble once lay against the schist along a plane of fracture.

North of Table Rock the ascent from marble to schist on the eastern side of Equinox Mountain is often steep and sometimes almost precipitous and the topography seems again to suggest the existence of old fault planes along which there has been differential movement between the marble and the schist. It seems likely that the youthful topography of this part of the region gave numerous fault line scarps where now are softened slopes of the schist formation.

The patches of calcareous rock found west of the main valley in the hollow around Beartown appear to be detached areas much like those found farther north within the range. In the southwestern part of Manchester a road from Sunderland village ascends the eastern slope of the range and crosses it to Sandgate village. Along this road in Sandgate township are detached areas of rock, probably belonging to the marble formation, which are separated at the present surface by schist. These various detached areas of limestone or marble have been explained as exposures due to erosion of a covering of schist, but examination in the field has not revealed contacts on account of the ubiquitous surface covering.

Considerations involving displacement between marble and schist on the east side of Equinox and flexure and displacement within the range seemed to the writer ample for the explanation of the occurrence of the marble in its present field relations around Equinox Mountain.

Arlington and Shaftsbury.

(Equinox topographic sheet.)

Location. Arlington lies south of Sandgate and east of Sunderland. It is bounded on the south by Shaftsbury.

General description. The eastern and southern slopes of Red Mountain northwest of Arlington village show well-defined scarps. The piedmont slopes east of the mountain give occasional outcrops of marble through the drift.

West of Arlington village the Batten Kill cuts through the range. North and south of the stream, west of the village, are frequent ledges of calcareous rocks. They are exposed chiefly close to the river and the hill slopes on each side of the stream are covered with drift. The calcareous rocks along the river in its westward course extend to a meridian about one-third of a mile west of West Arlington village and give place to schist.

In the narrow portion of the valley of the Batten Kill just west of Arlington village the actual breadth of outcrop of the calcareous rock is narrow. East of West Arlington village outcrops of such rocks occur on the piedmont slopes southwest of Red Mountain, but the actual extent of the calcareous rock is not certain because of the drift. North of West Arlington schist outcrops in numerous ledges close to the bank of Green River on contours lower than those occupied by limestone in the general vicinity. The structure of the limestone is irregular and again the field relations suggest that the schist has an inferior position.

West and southwest of Arlington village marble occurs on the west side of the Vermont valley at the base of the eastern slope of The Ball and gives place up the slope to schist. Contact was not seen. Prominent scarp topography on the east side of The Ball is lacking.

South of The Ball is Dry Brook hollow. Where this hollow opens into the main valley there occur near the junction of the piedmont road with one running east from it outcrops of the mountain schist, clearly in place. These outcrops are on meridians farther east than those occupied by marble ledges farther south on the eastern slope of Spruce Peak. The erosion which produced Dry Brook hollow apparently has not exposed marble which it seemingly should have done if the marble passes beneath the schist. In the hollow of Tanner Brook, southwest of Manchester village, schist was also found on meridians east of and on contours lower than those occupied by marble.

Northwest of Shaftsbury village the eastern slope of West Mountain gives somewhat modified scarps in the schist and the schist descends to contours so low that in places the relations give the impression that the schist forms the rock beneath the drift at places along the west side of the valley in this town.

In Arlington and Shaftsbury, as in Manchester and Dorset, topography and field relations are not out of harmony with the idea that the marble and schist have their respective positions of account of displacements by which the marble has come to have a position that gives the impression that it passes beneath the schist.

GENERAL SUMMARY.

It has doubtless become apparent to those who have read the foregoing pages that a question has been raised as to the stratigraphic position which has been assigned to the "Berkshire Schist" formation of the Taconic range, in its relation to associated calcareous rocks of probable Ordovician age. Proof has not been given that the interpretation of the age relations of the schist as described by other students is wrong. Suggestions have, however, been offered on the basis of study of field relations that these relations at many places are rather definitely in harmony with another interpretation and at other places are not apparently devoid of support to such interpretation.

At the risk of some repetition the field relations which have been emphasized in the preceding pages of this paper and in other papers will be briefly reviewed.

In the northern part of the Taconic range and in the southern portion of the Champlain lowland, certain terrigenous rocks which have their counterparts or closely similar types practically throughout the Taconic region and which consist of graywacke quartzite, or rather pure compact, quartzite, and various schists and phyllites, seem to occupy a position inferior to various calcareous rocks. In Benson, Orwell, Sudbury, Whiting and Cornwall the calcareous rocks just mentioned carry fossils and may be satisfactorily correlated with Lower and Middle Ordovician rocks of the lake region.

The fossiliferous limestones of eastern Orwell township join at the surface with marbly rocks at the northern end of the Taconic range in Sudbury and these in turn with similar altered limestones or marbles in Brandon township. The greatly altered marbly rocks of Sudbury and Brandon are for the most part of uncertain age, as fossils are generally absent in them, but from such fossils as have been found and from surface relations and to some extent on account of certain lithological features they are regarded as the eastward representatives of rocks of the lake region.

The marbles and other altered limestones found in Brandon extend with some interruption northward along the eastern portion of the Champlain lowland and southward along the Vermont valley. In Brandon and the areas to the north and south the marbly rocks are everywhere more or less extensively involved with dolomitic rocks, regarded as of Lower Cambrian age.

East of the Vermont valley and the Champlain lowland the dolomitic rocks which form a broad band along the eastern portion of the lowland and which make up most of the hard rock surface of the Vermont valley give place to terrigenous rocks which form the foothills and western slopes of the Green Mountain plateau and, in some cases, a part of the valley floor and that of the lowland. These terrigenous rocks are quartzites, or quartzites and schist, and make up what has been called the "Vermont Formation," regarded as of Lower Cambrian age.

East of Brandon and Rutland and elsewhere along the edge of the plateau the terrigenous rocks considered as a whole give an assemblage, which, in spite of differences in proportions of certain kinds of rocks and variations of one kind or other, is very much like that afforded by the rocks of the Sudbury hills and other parts of the Taconic range. The resemblance is indeed so strong that it was early suspected that these various rocks might belong to the same general formation.

In view of the apparently inferior position which the terrigenous rocks in Sudbury have to the calcareous rocks and from the field relations between those two kinds of rocks farther north in Whiting and Cornwall and also in the western part of Brandon, it seemed reasonable to infer that the terrigenous rocks in Sudbury are joined to those in the western edge of the plateau beneath the intervening marbles and dolomites of the valley. This distinctly does not mean necessarily that the terrigenous rocks now forming the edge of the plateau have at the present time their primary relation to those which underlie the valley rocks, for it is clear that the plateau rocks have been disturbed probably by normal faulting and probably also by thrusting which occurred prior to normal faulting. Northwest, west and southwest of Rutland parts of the terrigenous formation that lies beneath the calcareous rocks of the valley have been thrust into the latter and on account of later normal faulting the original thrust relations have been preserved. The terrigenous rocks now form the intermediate ridges in the valley around Rutland which have been described.

The reader should perhaps be reminded at this point that not all of the terrigenous rock making up the intermediate ridges

just mentioned is regarded by some students as belonging to a formation lying normally beneath the valley limestones and dolomites, but that on the contrary the schist is put above the marble and correlated with the schist of the Taconic range, which is also considered to lie above the marble and to be of Ordovician age.

The field evidence of displacement between the rocks of the plateau and those of the Vermont valley appears to be decisive. In the foregoing pages numerous indications of apparently normal fault displacement between the valley rocks and those of the Taconic range have been discussed. At some places the schist of the range descends to contours below those occupied by marble and in some of these cases and at other places the schist outcrops in the western floor of the valley east of the western margin of the marble formation. Scarps in the schist formation along the east slopes of the range are frequent. Topography and to some extent geological relations between schist and marble seem to bear out the idea of displacement between the rocks of the range and those of the valley. On account of recession of scarps by erosion some of them are now much less prominent than they seemingly must once have been. Talus from the scarps or drift conceals contacts between marble and schist.

North of the West Rutland valley, which it will be recalled is a subordinate one in the main Vermont valley, schist apparently occupies both the upthrow and the downthrow sides of normal fault displacements. In the eastern part of Sudbury the faulting may be followed in some places between masses of schist and in others between schist and marble. At Dorset Mountain and along the west side of the valley southward the marble occurs often at different levels and often seems to have a faulted relation to the schist similar to that shown in the eastern part of Sudbury. Outcrops of schist in the floor of the valley at the bases of steep eastern slopes of the range and frequently to the east of the western margin of the marble formation in the immediate vicinity as found north and south of Dorset Mountain, duplicate again the relations which are to be found in Sudbury. Such outcrops of schist seems to be due to erosion of overlying marble. The schist would probably be visible at other places along the west side of the Vermont valley if the surface covering were removed.

If the Vermont valley is interpreted as a great downthrow region between the Green Mountain plateau and the Taconic range one may by aid of the imagination restore in some degree the relations which obtained prior to the differential movements that produced the structural outlines of the valley. In imagination then the various rocks making up the floor of the valley may be thought of as elevated until the schist and quartzite which presumably underlie the dolomites and marbles are brought to the level which the terrigenous rocks east and west of the valley had prior to displacement of the valley rocks. This level would be somewhat higher than the present surfaces of plateau and range because these must have suffered some erosion. After such an imaginary elevation has been made the marble that now in general forms a belt or band along the west side of the Vermont valley is brought to a position in which one may further view it as part of a more extensive mass of similar calcareous rock lying above the schist formation of the Taconic range. The present distribution of the marble along the west side of the valley and its apparent relation to the schist of the range would then be circumstances resulting from displacement and the marble would be thought of as a dismembered part of a mass of similar rock that has now largely disappeared from the schist of the range.

The westward extension of the marble through South Dorset and Dorset villages in the valley south of Dorset Mountain and the fringe of marble on the north side of the mountain, as well as other present extensions of the marble from the valley into the range, could be explained as due to displacement, by which the marble was "dropped." On this view it is not difficult to understand why the marble in its extensions into the range at different levels gives place to schist westward along the present surface with no indications that the marble dips beneath the schist, and also why marble does not appear in the deep hollows of the range. Where marble, or calcareous rock apparently to be correlated with it, does occur in detached areas within the range it may be regarded as preserved through downfaulting, or possibly as the result of having been involved in thrusting.

According to the views just presented the apparent relations which exist now between schist and calcareous rocks in Sudbury and the towns north of it formerly prevailed over the Taconic range. It further becomes possible to understand why schist does not occur generally over the Champlain lowland above marbly rocks that are seemingly broadly to be correlated with the marble of the Vermont valley and the calcareous rocks of Sudbury.

If, as seems not unlikely, there once lay over the schist of the Taconic range a vast mass of calcareous rock which has largely been removed, it is probable that the erosion of this rock was accomplished prior to the dissection which the present surface shows. Some of the hollows within the range may have once contained some calcareous rock, but it is not necessary to assume that they did and that they were formed by the erosion of such rock.

As has already been discussed there are topographic indications of faulting in various parts of the Taconic range, west of its eastern borders, but the apparent faults in most cases extend through or between terrigenous rocks at the present surface and the fact of displacement is not so readily shown as when marble

or limestone rest against schist along a fault plane as is the case in places at the northern end of the range. The probability of the existence of normal faults at many places within the range is strong.

The terrigenous rocks of the Taconic region and the rocks that presumably once lay over them probably also suffered ancient displacements from thrusting and it is possible to imagine that relations like those shown by the marbles and schist in the Vermont valley near Rutland may once have been present within the range and that on account of heavy erosion such relations have been destroyed. Ancient peneplanation and later dissection have operated to obscure thrust relations among the rocks, if such occurred.

The considerations so far offered have been in the direction, so to speak, of restoring an extensive mass of calcareous rock on the schist of the Taconic range and of explaining the distribution of the marble along the west side of the Vermont valley as the result of faulting. It is not clear how much schist should be restored to the present surface of the range to give the surface on which the marble formation is supposed to have lain.

The normal faults that are regarded as having produced the structural outlines of the Vermont valley did not everywhere involve the same amount of displacement and so we see the marble occupying different levels. It also has different levels on account of unequal erosion.

GEOLOGY OF A SMALL TRACT IN SOUTH CENTRAL VERMONT.

GEORGE D. HUBBARD,

Oberlin College.

TABLE OF CONTENTS.

INTRODUCTION.

This piece of geologic work has been done mainly during the summer of 1924. It has been for nearly twenty years the custom for the Department of Geology and Geography of Oberlin College, located at Oberlin, Ohio, to offer a field course in geology as an organic part of the Oberlin summer session. The students registering for this course have numbered each year from six to twelve, and the work has been carried on three summers in southern Vermont.

The class goes into camp in some favorable locality for a seven-weeks' stay and works out in all directions a reasonable day's tramp from the base, all students returning each night. A report on the geology of the area is prepared by each student to complete and round out the study and gain the college credit for the course. In 1924 the class numbered nine and three colleges were represented, Otterbein and Oberlin in Ohio and DePauw in Indiana.

This place was chosen for the work in spite of its distance from Ohio, because it was not already worked and because it had a wide range of problems within a small compass. There are found in the area a considerable variety of metamorphic rocks, derived from Paleozoic sediments; several bodies of intruded, igneous rocks representing a similar range in time, and in variety of rocks, there has been much erosion, heavy glaciation and more subsequent erosion bringing the topography into its present state.

Our work consisted in making enough topographic map to learn the methods employed, in mapping the geology on the United States Geological Survey topographic map as far as we went, in working out the structure of the rocks, in mapping the glacial features so far as possible, in interpreting the succession of events comprised in the geologic history of the region, and in the gathering of data on the geologic resources available.

Location and Area.—The area covered is about six and a half miles north and south, and ten miles east and west, thus containing about 65 square miles or rather more than one-fourth of a 15-minute quadrangle. The northern boundary is the parallel of 42° 50′, the southern is about 42° 44′, or more exactly the Vermont-Massachusetts state boundary. The west line is the 73° meridian and the east is about 72° 47′, or the Whitingham-Halifax township line.

Geologically the area extends transverse to the structures in the metamorphics of southern New England and for this reason is very fortunately situated to disclose these structures.

Our area lies in south central Vermont, about one-third in Bennington and the rest in Windham County. Readsboro, Whitingham and Jacksonville are in the area, the first and second named villages are in townships by the same names. The town of Whitingham has recently been receiving notoriety because of the construction of a large power dam on the Deerfield River.

This river flows entirely across the area from north to south and the Wilmington and Hoosac Tunnel Railroad follows it the whole distance. Because of the construction of the huge power dam the railroad had to be moved up the valley walls much of the distance across the area. This and other items connected with the operations of the Power Construction Company, necessitated making many fresh cuts in the rocks, which greatly aided the geologic work.

Physiographically the area is a part of the New England Province and while it lies almost on the southern borders of the Green Mountains, it does not extend into them at all. It is a portion of the maturely dissected, glaciated upland, a partial peneplain with monadnocks.

Outline of Geology. There is little doubt that the first event recorded in the exposed rocks of this area was the making of limestone in the sea which covered the region. Then came clays and sands rarely well sorted, but varying from very sandy to very clayey in composition. Hundreds of feet of these, possibly thousands were laid, and probably other kinds as well, until what are now exposed became deeply covered.

Then came diastrophic and metamorphic processes, the former folding, mashing and uplifting the rocks, the latter carrying on changes within them until clays and shales became schists, and sands became quartzites, while the old limestones below became marbles. There is no way of knowing in our area how thick the marble is, nor what underlies it, but evidence from other related localities makes it clear that we may expect much schist and more calcareous rocks below the lowest in our section.

The foldings are very complex, the metamorphism is quite complete, the uplift has been oft repeated. And after some

metamorphism and probably after most of the folding, came repeated but meager intrusion of igneous rock. At least four periods of intrusion are recognized and four kinds of rock have been left in the metamorphics. Some of the igneous rocks are responsible for a little metamorphism along their contacts.

Outline of Topographic History.—Long before the events listed in the above paragraph were completed, erosion must have begun. Streams attacked the surface of all forms exposed to them. Weathering and erosion have made enormous inroads on the rocks of this region. Thousands of feet of material have been removed and the present forms carved from rocks uncovered by the earlier erosion.

The hills carry, in the outlines, the evidence of advanced maturity, but more careful scrutiny also shows that there are still preserved records of several cycles of erosion. The upper slopes are the more mature. Monadnocks rise above a general level reached by large numbers of the hills. This general level, higher in the northern and western part, represents the peneplain produced by a rather complete ancient cycle, the monadnocks, residual hills not even then removed. The remnants of this old erosion surface are probably the most mature slopes. Below these have been carved many wide valleys with slopes steeper, but yet mature, and on a level a few hundred feet below the upper peneplain, has been formed a less complete one, with much larger residual masses rising above. The cycle of erosion producing this second peneplain was interrupted and a third cycle was begun, but this latter only reached submaturity before it was itself interrupted by the great continental glacier which spread over all of Vermont.

It is probable that the ice sheet came at least twice and that it was gone long enough between the two advances to allow the streams time to do considerable interglacial carving in the drift-filling of old valleys, and some even in the rocks, where they had opportunity. Ice deposition and ice carving added many details to the topography.

When the ice sheet had finally melted away the last time the streams started in again, and while the time has been quite limited they have attained rather notable results in some places. Streams have carved out the drift and carried it away from many old valleys, opening them up again something as they were before the ice came. In many places they have encountered rock and have been held up thereby. Some valleys are narrow and rocky where the postglacial streams did not find the wide preglacial courses, other streams have worked all these thousands of postglacial years and have not yet encountered rock anywhere nor have they nearly emptied their old valleys of drift.

Thus glacial erosion and deposition and postglacial stream work have put the ornament and detail upon the preglacial framework made by long erosion on complex rock structures.

TOPOGRAPHY.

Relief and Pattern.—The highest land in the area is about four miles north of Readsboro, where a summit attains the altitude of 3,024 feet above sea-level. The lowest place is where the main stream, Deerfield, leaves the area over the Massachusetts boundary. The stream bed here is 1,040 feet high. Thus we have a total relief of almost 2,000 feet. East Branch of North River, flowing southeast from Jacksonville, attains a lower depth before it leaves the Wilmington quadrangle,[1] but within the area studied it has not cut below 1,200 feet.

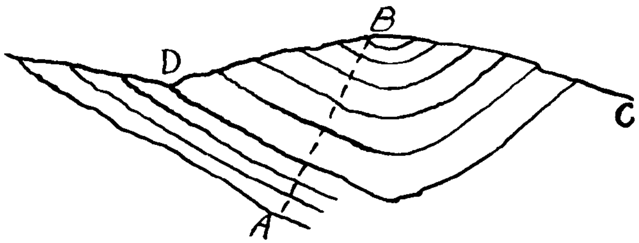


FIGURE 2. Structure section across the Deerfield valley east of camp and across the hill (B) through which the tunnel goes (line A-B on map). Strata of Readsboro dip very uniformly eastward across valley. Line A to B on section measures the thickness of Readsboro. Horizontal and vertical scale 1 inch = 1 mile.

While the highest land we have is over 3,000 feet, probably less than two square miles of area surpasses 2,500 feet, and this area is scattered in three small patches along the western side, one on the northern border of the territory, and one over the larger summit of the hill attaining the maximum.

Between 2,000 and 2,500 feet altitude there are about three square miles east of the river scattered in nine small patches, one of which, south of Whitingham is called Jilson Hill and contains nearly two square miles. On the west side are four areas, one a mile north of Readsboro of a few acres, one surrounding the summit peak of over three square miles, one on Lord Peak west of Readsboro of about 40 acres and a straggling irregular area along the western side, in places more than a mile wide and occupying seven to eight square miles. In all there are only about 14 square miles between 2,000 and 2,500 feet altitude.

The land below 2,000 and above 1,500 is by far the most abundant. A large area lies along the Deerfield and connected with it another bordering West Branch Deerfield River and extending over the hills southward beyond Lord Peak. East of the river all save the summits mentioned and two small areas on East Branch North River and on Deerfield, both below 1,500 feet, belong in the 1,500-2,000 feet area. This range of altitude thus comprises about 40 square miles.

[1] The reader will do well to have before him the Wilmington, Vt., quadrangle of the U. S. Geol. Surv.

The areas below 1,500 are nearly all along Deerfield and submerged above the big dam. A small strip follows up West Branch for two miles and a similar area lies around Jacksonville and down stream therefrom. All land below 1,500 feet probably does not make up more than 8 or 9 square miles.

Above 2,500 = 2 square miles.
2,500-2,000 = 14 square miles.
2,000-1,500 = 40 square miles.
Below 1,500 = 9 square miles.

Probably three-quarters of the whole area is between 2,250 and 1,600 and almost all the gentler slopes are within these limits. Many slopes above 2,250 are steeper and most of those below 1,600 are steeper except those actually on the flood plains. But while slopes over 2,250 in altitude are steeper, no summit is an actual peak. All are rounded domes or ovals. Plate XX. No upper slopes exceed one foot in six and many are as gentle as one in ten or twelve feet. In the great 1,600-2,250 level, slopes are rarely as steep as one in twelve and often as gentle as one in 25 or 30. One can go occasionally a half mile or more in a straight line without a change of level of 20 feet.

The lower slopes, below 1,600 feet, are steepest of all. Some are difficult to climb: 400 feet in 1,400 or even 1,200 are found and slopes of one in two are common for short distances of 200 to 300 feet. This steepness is not notable youth while mingled with some gentler slopes, but it represents vastly younger topography than the gentler slopes above. It must be considered very significant that the steeper slopes are in the lower levels, and that so large a percentage of the area is within so small a vertical range, and neither near the top nor near the bottoms of the valleys.

Drainage.—Drainage is essentially all above ground, although a few sink holes in two or three areas no doubt assist a little. The drainage pattern is a modified dendritic. The Deerfield is easily the master stream with a very meandering course across the area. About one-fourth of the territory is drained eastward to the Connecticut by East Branch of North River and its small tributaries. The chief branch of Deerfield is West Branch, nearly all of which is within the area. Brooks, runs, creeks, and rivulets in abundance remove all the water readily, except that contained in a few small lakes and marshy tracts to be mentioned in another paragraph.

It is obvious that in the main the present topography consists of preglacial stream-made forms mantled with drift, therefore, the streams wherever possible are in preglacial valleys. Preglacial drainage was certainly southward. Old valleys uniformly converge in that direction. The only notable exception to this statement is in the area about Whitingham occupied by Sadawga Pond and its feeders and outlet. At present this valley drains largely northward and its stream enters Deerfield headed upstream. No preglacial tributary could have joined the river at this place without coming in headed upstream for at least a mile of its lower course.

For a discussion of drainage modifications, read the glacial history on later pages.

Lakes are few and in almost every case partly artificial. Sadawga Pond was the largest natural reservoir. It was long ago enlarged a little by a dam at the north end, and now within the last year or so, this dam has been enlarged and the pond extended to conserve more water above the big dam for power purposes. The pond now covers over half a square mile and has a length of more than a mile. Plate XVIII. Its outlet is down a steep rocky incline for a half mile to the present Whitingham reservoir in Deerfield valley. Its borders are everywhere of drift and its shorelines lie on gentle slopes. Its area could be easily increased 50 percent by raising the dam 10-12 feet more. There is considerable peat in this pond, but owing to its repeated increase in size none is now above water. It has a small so-called floating island. This is not an island free to migrate over the lake, but to rise and fall where it is with the water. It consists of roots, stems and other vegetation (with some highly organic soil), which is attached to the bottom by long stems so it cannot leave its moorings, but can float and rise and fall as lake-level changes.

The second in point of size is Howe Pond in the far western part. This too is natural, but has been enlarged by a small dam across the east side. It is extensively used for boating, fishing, cottaging, and its waters are piped to Readsboro as a village water supply. This pond is nearly a mile long, but is somewhat narrower than Sadawga.

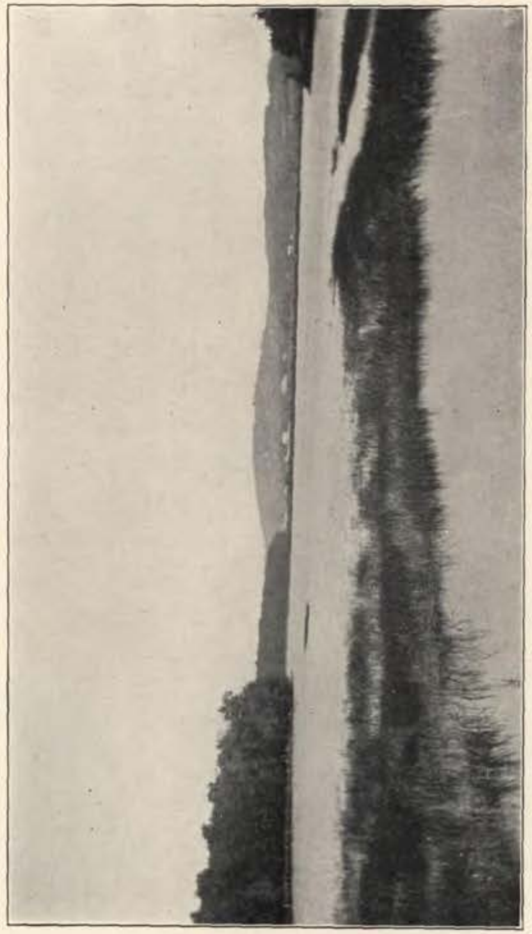
In the southeastern part of the area within three-fourths mile of the state line is a more or less circular pond 1,200 to 1,500 feet across, surrounded by drift and apparently wholly a glacial kettle. It drains by a small brook to East Branch.

Similarly, two smaller lakes, wholly kettles lie about two miles north of Jacksonville. One is entirely surrounded by drift, the other is simply a wider place in the stream where the water is retarded by a small obstruction.

Two miles northwest from Jacksonville is a small remnant of a larger pond now in a marshy, peaty area and well called Two-way Pond, for water leaves it at both northwest and southeast ends, one portion headed for Deerfield, the other for the Connecticut.

A pond one-fourth by one-half mile in dimensions is held up in a hanging valley above Jacksonville by an artificial dam. There seems to have been some pond here, and more swamp due to glacial interference with the drainage, but man has added to the

PLATE XVIII.



Sadawga Pond from the south with a part of Whitingham village on opposite shore. Swampy land in foreground. Rounded residual hills in far distance.

obstruction and made of it a quite serviceable mill pond. Apparently no use is made of its waters at present.

Many years ago a mill pond was caused in Readsboro by erecting a large wooden dam across the stream. The water was used for power until recently. Similarly two dams have been built and used in the West Branch, one near town and the other near Readsboro Falls. Neither had any natural basis of pond, but both are at excellent places to build dams.

In 1922-23 a very large earth dam was constructed across the Deerfield at a place about three miles above Readsboro and less than one mile below Davis Bridge and at the present Whitingham stop on the railroad. This dam has a huge concrete spillway underneath, which receives its water through a large funnel of concrete before the dam is quite full. The dam sets the water back in the river about 10 miles and destroys the usefulness of of the plant at Mountain Mills, two miles from Wilmington. It drowns the mouths of all tributaries in this distance and makes a reservoir, with a depth of water almost 200 feet in its deepest part, and an area of about six square miles. Lying as it does between the rather steep slopes of the valley it makes a very beautiful reservoir, which may serve many uses beside the turning of the three power wheels located a few miles down valley. The water is led nearly southward through a tunnel two and one-fourth miles long to a place where it intercepts the river, and the water is returned to the stream after descending about 400 feet in penstocks and passing over powerful waterwheels.

Glaciation.—The work of the glaciers is the most obvious in the region. The whole area was covered by the ice sheet more than once. Old buried drift is found in several places as evidence of at least one early ice invasion. The later fresh drift abounds everywhere except on occasional nearly bare rock surfaces, testifying to the work of the Wisconsin glacier.

When the ice came the region had already passed through its several cycles of erosion, with the exception of the one called postglacial. Hence the topography was mature to advanced mature and in places old. The drift mantles all these old erosion forms, but they are discerned through the cover. It is from a study of these partly concealed forms described above that we know what the country looked like when the ice came.

Postglacial Erosion.—We saw a youthful cycle, which had been started on advanced mature topography, interrupted repeatedly by the ice. Each time the ice melted away the streams resumed their task. Interglacial stages were as long as postglacial time has been, hence each interglacial erosion cycle may have advanced as far as the present postglacial cycle has. And after its meager start each such cycle was again interrupted. Finally the ice melted away for the last time and the present cycle began. Little progress has as yet been made. Many drift forms and even glacial lakes still persist undisturbed by stream work. Streams have not nearly cleared the drift out of their old valleys. In places they have cut through the drift to rock, but even with that accomplished, great quantities of drift still partly obstruct valleys. Little or no new soil has been made by rock decay. The drift lies on fresh rock just as when first deposited.

Yet a start has been made and as time goes on the re-excavation of the earlier valleys will be accomplished and the deepening of rock valleys to base-level will proceed. The interrupted cycle will thus be taken up again and pushed on to completion. Post-glacial erosion now just begun will, if time allows, produce just as complete a cycle as either of the erosion periods that passed in preglacial time.

DESCRIPTIVE GEOLOGY.

General.—The area under consideration has a larger variety of rocks than is generally supposed, but not as wide a range as some areas of similar size.. Metamorphic rocks greatly predominate and these are very largely of sedimentary origin. The metamorphics are marbles and schists. The former were made from somewhat impure limestones and now contain a considerable number of accidental minerals, graphite, pyrite, quartz, tremolite, several micas and other minerals. Among the schists, quartz-mica types make up almost the whole list, but the proportions of the two minerals vary much. Some are so siliceous as to be almost quartzites, others so micaceous as to be essentially phyllites. The schists also vary considerably in their accessory minerals. Albite occurs in some, garnets and tourmaline vie with each other for position; magnetite, pyrite and various amphiboles are common. Several different micas in varying proportions add to the complexity. Schists differ much in color. Gray predominates in the central part of the area, blue is common in the western third and green to greenish black in the eastern portion. Some of the schists are brilliant and sparkling with their fresh micas. Some are dull, even when fresh.

The schists differ much even in short distances in their physical properties. Some split very nicely for economic uses, others seem to have no cleavage. Some are strong and resistant, some powder up and crumble readily under the hammers of weather and decay.

The igneous are all younger than the metamorphics. They occur in considerable range of type and condition. There are very basic rocks and dikes of almost pure quartz. All igneous rocks are in dikes and the range in size runs from the merest stringers to bodies 200 to 300 feet across, with occasional occurrences nearly twice as thick. No sills or larger bodies are known. The dikes are always in the metamorphics and in all types of metamorphics, they are scattered pretty freely all over our area.

Intersections of the several kinds are known in sufficient variety to make the order of intrusion of the several types perfectly clear.

All the intrusions were made when there was a thick cover over the rocks now at the surface, so that the effect of intrusion and the types of dike crystallization are such as occur under pressure and thick cover. This may be interpreted to mean that the intrusions preceded the earliest cycle of erosion whose records are still extant in the region, which may put most of the igneous activity into the Paleozoic age. No intrusions found were made so recently that they came anywhere nearly to the surface, that is, what was the surface when the intrusion occurred.

Sedimentary rocks are all very recent and as yet wholly unconsolidated. They belong to the Pleistocene and the Recent and are all glacial, glacio-fluvial or purely alluvial deposits, except that of course a few lacustrine deposits lie below the waters of present lakes, and in the beds of extinct lakes. These all would also be Pleistocene and Recent. The sedimentaries lie unconformably everywhere over the ancient crystalline metamorphic and igneous rocks.

METAMORPHIC ROCKS.

Sherman Marble.—The oldest rocks are the metamorphics, and the oldest metamorphic is the marble to which we have given the name of the town where it is most extensively exposed and worked—Sherman, on the Hoosac Tunnel and Wilmington Railroad.

Marble was found in about a score of places all in the southern central part of the area studied. Nearest to Readsboro of all were the meager finds on the nose of the spur in the loop of the river. This would be just east and southeast of town on the hills above the old box factory now being removed. Loose fragments of the rock were first found, then larger boulders and a few pieces possibly in place. The marble seems never to withstand weathering by solution more than a few rods from the outcrops where known crops occur, hence we infer that where only loose pieces were found the ledges must be near. Farther up the slope eastward on this spur about a half mile from the village end of the spur, and east of the large schist ridges crossing the spur from north to south are several pieces of float and a few ledges of marble. These occurrences are so placed as to make it clear that some of them are actually in place, and all of them very near their sources. They continue entirely across the ridge from north to south. Those on the east side of the strip dip eastward, those on the west dip westward. Across the river northward from these occurrences are the outcrops first seen in our area. They were right near camp on the slopes around and above the Bailey home and on pasture land belonging to the

Whitneys. Zigzag lines of marble (Plate XIX-A) outcrop here constituting at least three strong layers easily traceable in the pasture, and between them are weaker layers that weather down and cannot be seen. These three stronger layers converge northward rapidly, the inner pair meeting in the leveler area and the middle pair meeting just at the edge of the steeper slopes, while the outer pair run under cover of waste from the overlying rocks and disappear before they meet.

The outer layers can be traced up the hills northward to altitudes of 100 to 150 feet, at least, above the outcrops in the pasture. The lines of outcrops can also be traced down to the private road in one case and nearly to it west of Bailey's barn in another case.

The outcrops on the south side of the stream and those on the north are no doubt connected below the river, but they have been cut out very completely near the stream and cannot be actually traced across. Approximately on the eastern limb of the structure, or better on the outer layer of the east side as defined above, and down slope 200 feet or so below the private drive occurs a big, cold spring with marble showing in two or three places about it. Sink holes back in the pasture suggest a connection here. Surely the spring waters come out of the marble, probably they are the same that go in at the sinks farther north.

Dale[1] describes an outcrop of graphitic, micaceous, calcite marble about one-fourth mile north of the local dam in Readsboro village. This occurrence we surmised and needed in our findings, and we searched for it carefully but did not find it. We did not know when in the field that it had ever been found. We did find, however, the formations that overlie the marble in a good anticlinal structure in this locality. The map shows Dale's find of marble and our interpretation of the succeeding beds. This is apparently in the same anticline as that near the end of the nose of land in the loop of the river, *i. e.*, the first outcrops described above.

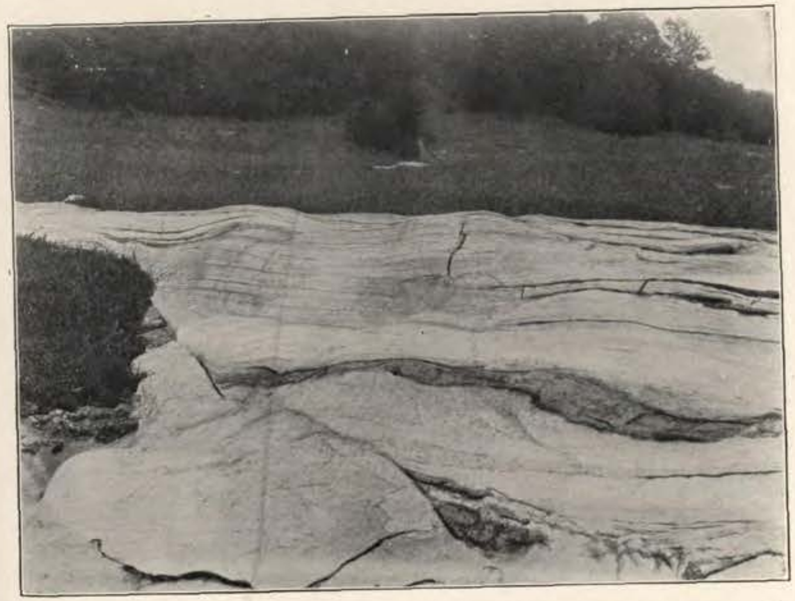
Another notable occurrence of marble has been extensively worked at Sherman on the railroad, a little over two miles down stream from Readsboro. Railroad construction necessitated a cut of considerable extent in the marble, and a few years ago a large plant was put up to make carbide of calcium from the marble. The quarry opened shows a fine section of the marble dipping eastward into the hill. And southward for nearly one-half mile a ridge of marble, can be traced, rising as a small hill in the side of the valley. So strong is the south pitch of the anticline that it goes completely under younger layers before the state line is reached.

[1] Dale, T. N., Calcite Marble and Dolomite of Eastern Vermont, U. S. G. S., Bull. 589, p. 52.

PLATE XIX-A.

Sherman marble near camp, S-25. Several bands of outcrop (strong layers) between covered intervals (weak layers).

PLATE XIX-B.



Sherman marble at S-25, near view. Lenses of mica, darker bands, and quartz cut off in center and left, by a fault.

This area of marble continues northward more than a half mile from the old carbide plant and the railroad cut. Some of the distance the marble is covered with waste, but northward under the power line it can be seen almost continuously for several hundred feet. Again on the west side of the river a few hundred feet upstream from the Sherman Bridge are small outcrops which were opened commercially long ago. Here the beds dip west and at Sherman they dip east, and the whole structure pitches northward and southward and carries the marble down out of sight at each end. The total area of marble exposed, including all that is covered with waste, is probably not much more than a mile north and south and less than 2,000 feet wide in the central part. Since the sides converge so rapidly in the pitching anticline the area is narrow and tapering at both ends.

About one mile east of this area occurs a very interesting group of marble outcrops. From the first outcrop, one mile east of Sherman, the area continues a mile east and a mile north with frequent ledges of marble. For the sake of a name this group will be called the Whitingham area. It will thus be distinguished from all others, even though the Sherman area is in Whitingham township. All marble outcrops in the area are long and narrow, trending north and south. See map. In this square mile, at least 12 patches of marble are found. In many cases the same patch shows dips in opposite directions as if it were the crest of a little fold or wrinkle. At least six wrinkles are known across the northern part of the square mile, large enough to bring marble up to the erosion surface. In the middle part as many wrinkles are known but only three seem to bring marble up, while in the southern part at least five are known, three of which bring marble out. The eastern marble patch in each of these three sections may be in the same wrinkle. Possibly the western patch in the northern section may be the same as the western in the southern section. No other connections are even probable. There must be, therefore, at least 14 wrinkles in this little area. The whole series seems to be in a larger anticlinal structure of rather short dimensions north and south, and pitching steeply at each end under younger strata.

In the north-south valley west of Sadawga Pond about three-fourths of a mile southwest of Whitingham village, marble has been quarried on the east side of the brook and burned on the west side. Dale[1] mentions and briefly describes this marble, but we did not see it owing to the condition of this valley in consequence of the Whitingham dam. Either water sets back over the place, or brush cut along the reservoir shoreline or the new road improvements conceal the place. The marble is described as coarse, abounding in phlogopite scales up to one-half inch across,

[1] Dale, T. N., Calcite Marble and Dolomite of Eastern Vermont, U. S. G. S., Bull. 589, pp. 49-50.

with graphite, quartz, and rarely actinolite. This occurrence is in line with the structures found a mile farther south and mineralogically remarkably similar. It no doubt outcrops here because brought up by a wrinkle similar to those farther south. It is put on the map in what is left blank as water area and the formations next it are omitted.

This occurrence lends more color to the suggestion later, that marble may be near or at the surface beneath the water in Sadawga Pond.

In no other part of the area is marble found. Each occurrence is in a known anticline, but many anticlines are known with no marble.

Since in all these occurrences the marble dips outward from an axis beneath other layers, since all the marble in the area is quite similar, and since the rock succession above the marble is always the same, it seems reasonable to infer that the marble is continuous beneath other rocks from one area to another. And if it underlies thus a considerale portion of the southern part of our area, we also infer that it underlies the whole area. Evidence of a continuation of its immediately overlying beds will be presented later. They are known all across the western part of the area, and our general structure is such as to lead to the belief that they go under younger rocks in the eastern part.

Marble of similar character and relations is known in several places northward beyond the Readsboro area. In previous work done in 1916 and 1920 our party found the marble areas reported by Dale[1] in Binney Brook two miles northwest from Wilmington, in the Wheeler Hill two miles west of Wilmington and south of the Deerfield, also up the hill in several places even to its summit, in Mt. Pisgah three to four miles north of Haystack Peak and again south of Haystack Pond.

With so much evidence of the continuity of the Sherman marble under most of the country, two further suggestions may be made. The first concerns Sadawga Pond area. While no marble was found anywhere around the pond, and while the beds immediately overlying the marble were not found in this area, it may be that the land is low where now stretches Sadawga Pond because the marble was reached by erosion. For comparison it would not be difficult to imagine drift so placed around the Whitingham marble area as to retain water and similarly make there a considerable lake. If marble is in the Sadawga Pond area at the surface, sink holes may be expected some day to develop and offer subterranean outlets westward for the waters of the pond unless the syncline between it and the river is too low to let the water under.

The other suggestion is of the same nature and is based on

[1]Dale, T. N., Bull. 589, U. S. G. S. (1915), pp. 47-49.

equally good evidence. It is to the effect that Howe Pond, two to three miles west of Readsboro may lie in another area in which the marble has been reached. Both north and south of the pond outcrops of the rocks immediately overlying the marble were found. Drift covers much of the rock and together with the water completely conceals the marble if it does occur here. It should be urged in support of these suggestions that the marble must be near, if not actually at the surface of the rock just below the drift in both places.

The marble is usually gray to white, coarse crystalline, granular, and does not hold together very well, but at Sherman some of it is very firm and would handle well. The friableness in other localities may be due to weathering, for we have been unable to break deeply into it in any of the occurrences except at the Sherman quarry.

Other colors than gray and white are known. Pink tints occur in the old pit across the river from Sherman. Yellow bands occur at Sherman. Pink marble in beautiful tints is found in the extreme southwestern outcrops of the Whitingham area in square e-34 and again at h-30 in the extreme northeast part. Yellow tints occur near camp at S-24, and in the large area at e-f-28-29.

In texture the marble is usually medium grained, but near the top some coarse beds appear and where the graphite is coarse the calcite crystals are generally large too. In e-f-33 an old quarry showed much coarse calcite with crystals at least an inch through. Some of this coarse material was yellow, other masses red, resembling very much flesh red feldspar. Iron is present in small amounts and probably is the cause of the color. This occurrence seems to be simply recrystallized marble. It has been opened for commercial purposes and fine exposures made.

Accessory Minerals in Sherman Marble.—The marble is rarely pure calcium carbonate even for single layers, and for short distances. Nearly every sample gives a feeble iron reaction. Dolomite is common. The formation could well be called dolomitic for many samples, all that were tested, gave a strong magnesium reaction.[1] But in some places accessory minerals make up a very considerable part of the rock.

At Sherman graphite is common, particularly in the lower layers exposed. Crystals as large as peas occur, but more frequently they are mere specks to the size of pin heads. Much of the graphite is in bunches, but some is in more or less continuous layers, making the rock gray and streaked. Samples could be

[1] In cold dilute hydrochloric acid every sample examined, and from all localities, effervesced freely at the start. After a few moments the reaction became slow and the addition of fresh acid failed to stimulate it. Yet in time every sample completely dissolved in the cold acid, except for the small residue of silica and silicates entangled in the sample. Heating at any stage in the slow process stimulated the reaction. On these results it is believed that the formation contains both calcite and dolomite. The acetic acid separation was not tried.

taken having 10 to 15 percent of graphite. Most of it is foliated or flaky, some shows a radiate pattern. Graphite is not so common higher up in the Sherman outcrops, but occurs nearly all through the rock. In other places it is also sparing. At camp, on the Whitney farm one-half mile east of Readsboro, many small crystals were seen. Across the river south the graphite is also rare, and in the Whitingham group of outcrops it is only occasionally seen. No outcrop is so thick as that at Sherman, and it seems probable that the graphite is confined largely to lower layers. Other minerals are much more common in the upper layers.

Tremolite and actinolite are abundant in most of the localities. They seem to belong much more to the upper part and to become rare downward. Some very showy specimens were collected near the upper contacts, also near the railroad at Sherman. This latter occurrence would not be near the contact. The crystals are long, prismatic, often very slender and range in color from white through delicate tints of aquamarine to green and even dark green. Some are as large as cambric needles, others can be seen only with a lens. Tremolite is usually in small bundles of crystals two to four similar in size, then two or three more lying at an angle with the first. Actinolite on the contrary lies in long bands of several inches, with many crystals making up the mass, and all more or less in the same direction, but not making straight lines. They originally may have been made straight, and then bent by more recent movements. As the contact with the overlying formation is reached these minerals become more common and in some thin layers where the marble gives way to the typical Whitingham quartz-mica schist, make up 20 to 50 percent of the rock.

Micas are probably the most common accessory minerals, and several species occur. Stringers of mica, mostly muscovite and sericite, occur at all depths in the marble. Some are several feet in length and vary in thickness from one inch down, representing a variable layer or lens in the sediments. Other stringers are even more extensive and constitute layers many feet long and wide, but never of uniform thickness and rarely more than two or three inches. In such cases muscovite is not alone. In some horizons, notably toward the top, both at Sherman and near camp the muscovite is finely divided and scattered rather uniformly all through the layers. In such cases graphite accompanies the mica. The most striking occurrence of mica, however, is at h-30 in the pink marble. Here phlogopite in crystals from one-half inch diameter down occur in great numbers. They are characteristic bronze colored with submetallic luster, and yellowish brown by transmitted light. Single flakes, scores in one plane occur, also bunches of flakes and crystals, two or three inches across. When the rock weathers these bunches stand out

as brown rosettes looking like a withered flower. Scattered through the pink marble they make very showy specimens. Phlogopite in some samples taken, constitutes as much as 25 percent of the rock. This is the only place where phlogopite was noticeable. Dale reports it in the quarry now under water southwest of Whitingham.

A green mica also occurs freely in the upper part of the formation. This is soft, brittle, nearly transparent, and coarser than much of the chlorite, in younger formations; but it probably should be called chlorite. It is mingled with the phlogopite of the last occurrence in large masses and is sprinkled through the marble at d-33. It occurs with actinolite at Sherman and in the upper transitional layers at S-24 near camp. Plate XIX-B.

Pyrite is common in minute crystals in the marble, but is nowhere noticeable. The largest crystals seen were scarcely one-sixteenth of an inch in diameter and they were never seen in aggregates, but finely disseminated. Quartz crystals occur near the upper transition zone probably due simply to the metamorphism of quartz grains in the sedimentary beds, as the latter became more sandy. Tourmaline occurs in many places in the marble. Black is the predominant color, but red has been seen. At h-30 black tourmaline crystals pierce through the chlorite in every direction in crystals one-third inch long and downward, and from one-thirty-second of an inch in diameter to scarcely visible. Iron stain in the weathering marble is rare. The pyrite is probably responsible for some of it.

Talc was found with chlorite and actinolite in the marble at h-30, but seems to be rare here and was not noted elsewhere. It may be secondary after the hydromicas or, better, after actinolite and tremolite.

At e-f-34 the marble is shot by a quartz dike and considerable mineralization has occurred. While this intrusion occurred long, long, after the making of the marble and will be mentioned in its proper chronologic sequence, it seems well to mention the quartz and tourmaline in the marble as a result of the intrusion. Little quartz stringers apparently of the same sort are found in the marble near camp in considerable numbers, and at Sherman XY-36.

It becomes obvious from the discussion of the last few pages that the marble varies visibly from place to place. Yet these are all within a narrow range and do not seem to indicate more than one formation. Because of the position of the folds of the marble with reference to the depth erosion has gone, the base of the marble has not been found. Drillings no doubt would find it and erosion may later uncover its lower contact, but that has not yet been done in our area. The thickest exposures are at Sherman, where fully 200 feet can be seen. It seems probable that if the whole anticlinal structure here could be seen, even where the bed of the river lies, we should be able to see two or three times as great a thickness of marble. We believe the structure and forms here make it clear that there is at least 600 feet of the marbles, but only 50 feet or so can be seen on the west side and probably not more than 300 feet on the east side. The river and its alluvium occupy and cover the middle part of the anticline.

In the Whitingham area the crests of the marble folds are from 300 to 400 feet above the highest marble exposed at Sherman. Thus probably if the Sherman folds were restored the marble would still be higher in the eastern area than at Sherman. Dissection, therefore, in this eastern area comparable with that at Sherman would no doubt uncover lower marble than shows at the latter place. That the top of the marble is much lower in some parts of the area than in some of these where it is seen, is obvious, for the rocks have been cut down along both rivers below the levels at which marble is seen in the hills south of Sadawga Pond, yet without exposing even the top of the marble. Necessarily the marble is, therefore, involved in the folds just as are the layers of rock above it. This interpretation is well supported by the fact that every occurrence of marble known in the area is in the crest of an anticline and that younger overlying rocks dip with it away from the axis of the structure on each side.

The Whitingham Schist.—This formation has been found immediately overlying marble in every occurrence of the latter where the contact could be found. It has been located in R-25, S-24, S-28, and W-32 on both sides of the marble dipping consistently away from the axis of the marble fold, in the eastern part of V-36, *i. e.,* on the western flank of the Sherman area of marble and doubtfully on the eastern flank also, in a dozen or more places in the Whitingham marble area, contiguous with marble. Because of these relations generally, all over the area we have mapped it in interruptedly except where marble shows through. Because it is so well developed here and because this is easily the largest area known, we have named the formation the Whitingham Schist from the township in which it here occurs. In four places lying almost perfectly aligned we found what seems to be the same formation. These outcrops are in the western part of our field at E-7, E-14-15 and D-E-16-17, D-21 and D-26. We considered two of these to be special phases of another formation higher up (the Readsboro) when they were first found. When their true relations became known we were forced to interpret them as Whitingham, for all four are perfectly consistently located if so interpreted, while if called Readsboro, a fault must be invoked to explain their occurrence here. We could find no other evidence of faulting. In the large area D-E-14-17 the anticlinal structure was finally found with opposing dips on east and west sides. Forest and drift cover so much of this area

that we could not connect the several outcrops, but believe if the truth were known, they would be found all to line up along the axis of a large anticlinal structure.

It seems reasonable to suppose, with the above distribution and structure, that this formation is continuous from one outcrop to another over the marble and under the next layers above. It would thus be wanting only when the marble shows through.

The Whitingham schist resembles notably certain layers in the Readsboro (figure 3), but differs strikingly in some characteristics. It should be called a quartz-biotite schist with calcite. Nearly half the rock is quartz in small even grains and nearly half is just as even grained biotite. In addition calcite occurs in crystals in many parts of the rock. Some hand samples effervesce freely in scores of tiny centers when bathed in hydrochloric acid, others very sparingly. All samples taken show calcite in spite of the fact that two were only one or two inches from the surface. The rock is even grained wherever seen and remarkably similar

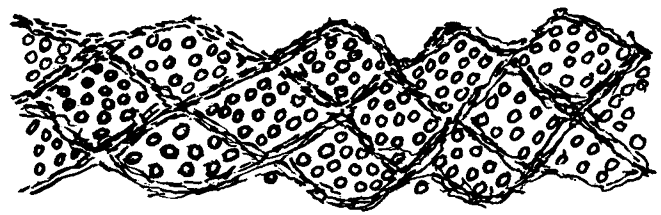


FIGURE 3. Pebbled Readsboro. A mesh of biotite enclosing bunches of feldspar and quartz which when weathered looks a little like a pebbly conglomerate.

in appearance from place to place. Pyrite crystals are rare, but are present, as confirmed by the brown weather stains where they have been oxidized. Muscovite and chlorite also occur.

The Whitingham formation has a thickness in S-24 of about 40 feet. Actual measurements are probably impossible. We found no place where they might be taken because both contacts were not found opposite each other. In S-28 it seems to be thicker than at camp and in the large Whitingham area it is certainly more than 100 feet thick. No thickness could be ascribed in the outcrops of the western part of the area because the base was not exposed. Obviously the formation thickens eastward, but since all the full-thickness outcrops are within an east-west range of three miles we cannot say what happens farther east or west from these.

In the squares e-f-34 southwestern corner of the large marble area, and near the road, a quartz dike was found cutting across both marble and Whitingham schist. This is the only dike noted in the latter. The dike was a good mineralizer, for in the Whitingham beside the dike are pyrite, red and black tourmaline, calcite, and quartz. In the dike is much black tourmaline.

The Whitingham schist has no sharp boundary below, but grades up from marble to schist. In the transition zone, which may be several feet thick is a wealth of chlorite and actinolite, as well as the essential minerals of both marble and schist. In some places these two green minerals make up almost the whole rock for several feet. Some very attractive specimens could be taken in S-24. The biotite of the schist seems to have been formed before the quartz. While actinolite is the most abundant amphibole along the contact at the camp outcrop, tremolite is by far the most abundant at the Sherman outcrop. Layers one-half to one inch in thickness of almost solid tremolite occur. Other layers consist almost wholly of tremolite and fine grained phlogopite.

The upper contact of the Whitingham with its successor is also a transition. Usually it is gradual and since both are mica-schists it is difficult to locate. The gradation covers from 5-20 feet of thickness. Either type is distinct enough, but the intermediate beds are truly neither Whitingham nor Heartwellville. The calcareous phase disappears first, then the percentage of silica declines and the texture becomes coarser. The change in mica is more abrupt.

Heartwellville Schist.—This schist was first seen in the hills above camp overlying the Whitingham and marble. Its identity with the rocks of the large area in the western section studied was not at first suspected, although every one of us had trouble in pointing out any difference between them. It was called the sub-Readsboro here because of its position, and the only real difference found was one of position. When it was discovered that the beds in the west called Heartwellville dipped below the Readsboro on both sides of the area our only distinguishing character failed and we all were forced to class both as one. Since the town of Heartwellville lies upon the large area it seemed but fitting that that name should prevail for the schist. The thrill of discovery caught many of the party when the true relations of the Heartwellville were made out.

The large area in the west is narrow to the south, but widens rather rapidly, until in the latitude of Howe Pond it covers about two miles. This width is maintained across the area northward and this type of rock runs off the area westward nearly all the way north of the pond. The formation dips under true Readsboro on the west, a short distance beyond the area, and northwest of Howe Pond, just as it does on the east near West Branch. Around Heartwellville and Howe Pond the drift covers all so deeply that we did not map bed rock. In four patches along the axis of the area as described under Whitingham schist the older rock protrudes through the Heartwellville.

Eastward from this large area the formation appears in many small outcrops. First in the steep slopes one-half to one mile north of Readsboro along the road to Heartwellville many great boulders and probably ledges in place show in the steep valley wall. No authentic dips were taken here. Then one and one-half miles farther north in the top of the hill a small patch shows through. This area has east dips on the east and west dips on the west. North of the "square" in Readsboro, for a few hundred feet, in the rock slopes, the Heartwellville is found dipping at a low angle westward, and a few yards farther east it descends sharply to the east. This area may be traced southward into the east slopes of Lord Peak and one-half mile south of town. Up the nose east of town, beyond a narrow N-S strip of younger Readsboro schist outcropping conspicuously near the railroad yards occurs a long narrow area of Heartwellville in a distinct anticline. This is probably to be correlated with the structure across the river north in the eastern part of town, where the fold is high enough to expose the marble.

A few hundred feet farther east on this hill comes in the area which surrounds the Whitingham and marble of the whole camp area. Heartwellville schist is easily traced entirely across the ridge from river to river, in two bands each 200 to 300 feet wide, broadening a little perhaps northward. This area seems to extend across the river south into Lord Peak, and it can be picked up with ease on the north side of the river at camp and

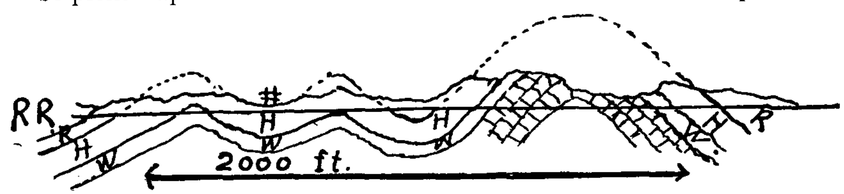


FIGURE 4. Structure section nearly east and west through new large power plant. RR = railroad level; dotted line = restored folds; irregular solid line above railroad = present surface. R = Readsboro; H = Heartwellville; W = Whitingham; block work = Sherman marble. ‡‡ = Power plant. Note frequency of wrinkles.

both bands can be traced back into the hills, the east strip much more successfully, the west mainly by boulders and by associated beds. The two bands converge and meet in S-23, and the crest of the fold where they meet pitches northward under the next formation at a rapid rate. The convergence of the two bands or strips testifies to the pitch even on the rapidly rising ground. The beds dip outward on each side.

Another area of Heartwellville occurs around the new power plant and southeastward. On the county line and the wagon and railroads is a small wrinkle which brings Heartwellville above railroad-level. Just east of the power plant is a similar small fold. These both pitch north into the hills and south so sharply that they were not found across the stream. Figure 2. Going on east beneath the power lines this formation rises again sharply in an anticline. The layers can be traced northward into the hills and around the end of the Whitingham and marble, and back southward on the east flank of the structure. The larger area surrounding Whitingham schist on the north and extending in two strips southward continues in the two strips for a mile and a half or essentially to the Massachusetts state line, just north of which they meet again and go under the Readsboro formation to the south. The Heartwellville thus completely surrounds the areas of marble and Whitingham in this (Sherman) locality. The river has cut out so much material that it has left the distribution rather in confusion, but the structure is clear enough.

Another area of Heartwellville surrounds the area of Sherman marble and Whitingham schist described from the Whitingham area. This border was not found every foot of the way. It was obvious at many points on the west side and around on the northwest, at one or two points on the north, in several patches on the northeast, rather continuously all along the southeast and across the south. Thick drift and swamp conditions conceal the rock in several places, timber interferes with study somewhat. We believe, however, that the mapping is not more than 100 to 200 feet in error anywhere around this area and usually much closer than that. In this whole area the dips are outward and carry the Heartwellville beneath the Readsboro.

Only one other area of Heartwellville was found and that is in some doubt. It may show in a small area on the hill about one-third mile west of the county line and one mile south of our northern boundary. This does not seem to be a reasonable place for the formation to show and no doubt is an error in identification.

This distribution taken with the structures to be described in later paragraphs, suggests very strongly that the Heartwellwill underlies the whole area except where the older formations are at the surface, and that in these areas it has been eroded completely away.

Mineralogy of the Heartwellville Schist.—This formation has but few minerals and two of them vary widely in their percentages. Quartz and sericite make up 90 to 95 percent of the rock. Specimens from A-18 are put at 96 to 97 percent sericite and less than 1 percent quartz, while one near the power plant is estimated at 7 percent sericite and 90 percent quartz. The former are very near the top of the formation, while the latter is probably near the base. At both D-27 and Q-27 sericite is estimated at 90 percent or over, and these are doubtless both near the base. Many samples show quartz and sericite nearly equal. We do not believe the proportions of these two minerals are definitely related to the zone in the formation. Apparently highly siliceous and highly micaceous layers can occur anywhere in the formation. Sericite is clear, silvery, shiny to delicate green in the lower and

middle parts and distinctly blue to blue-gray in the upper part. The latter is seen at A-18. At L-21 in the top of the Heartwellville we took samples in which the sericite was clear to green in color. At E-F-19 which must be near the base of the formation, beautiful silvery to green sericite makes up nearly half the rock. Color of mica seems to bear no relation to proportion of quartz and mica. Quartz is usually clear to milky, but pink was noted at D-27.

Garnets of a red, almandite type occur all through the formation, so far as we could discern, with the exception of the upper layers at A-18. They make up as much as 3 to 5 percent of the rock in many places and probably 10 to 15 percent in selected layers. They range in size from one-fourth inch down to tiniest specks, and some little beds, one-eighth inch in thickness are almost solid, tiny garnets. Tourmaline, too, is of frequent occurrence though not as widely distributed as garnets. It is always in black crystals usually long, slender, but at A-18 stocky. At D-27 crystals one inch long were taken. Perhaps they are a little more frequent in the blue sericite mica schist than in other forms. They seem to bear little relation to bedding, but pierce the schist in every direction.

A bronze or brown mica was noted in one or two percents at E-F-19 and at V-31. Graphite makes up one percent of the rock at L-21. This is near the top and is not related to the marble. Biotite was noted in several places in tiniest specks and flakes, occasionally parts of flakes that are chlorite at the other end. At E-F-19 it makes about one percent. Chlorite was noted at D-27, but only in about two percent and it may have been secondary after garnet, though this was not suggested by the specimen. It occurs in soft green flakes and in aggregates in several places.

An interesting occurrence of boulders found at J-31 contains more chlorite than most of the formation. It also has sericite, quartz, magnetite, in very small octahedra and ilmenite plates in the chlorite bunches, and fine crystals and bunches of crystals of feldspar, apparently albite, though no optical tests have yet been made. We have samples to be further studied. These boulders were nearly a mile beyond (southeast of) the Heartwellville border. But northward back in Heartwellville, ledges of this same rock occur. It does not seem to be abundant. It was first noted as probable Readsboro boulders and later was found as beds in the lower formation.

In thickness the Heartwellville seems to decrease rather consistently eastward and probably southward. The thickness cannot exceed 300 to 400 feet in most of the outcrops east of Readsboro, for it occurs only in narrow strips of 500 to 800 feet wide, with dips usually of less than 60°, and in the eastern area of less than 45°. There is in almost every area some wrinkling which causes repetition of part of the layers. In the western part, if there were no wrinkling, one would readily estimate 3,000 feet, but there is no possibility of the thickness being half as great as that, for on each flank of the large anticline are several folds from a few feet to a few hundred feet wide. Probably 1,000 to 1,200 feet is thickness enough to ascribe to the formation anywhere in the area.

This formation lies in a large anticline in the western part and several smaller ones in the central part and each fold has wide, broadening a little perhaps northward. This area does not smaller folds all over its back. The smaller folds have wrinkles of a few feet in width all through their structures. The large anticline in the west pitches sharply southward so as to carry the whole formation down out of sight beneath the Readsboro a mile from the edge of our area. In the town of Readsboro and eastward beyond camp, fold after fold occurs. Four or five are known, the largest lying farthest east and sending its eastern limb down below Readsboro schist just east of camp. These folds like those on the big anticline in the west are adorned with smaller folds and wrinkles down to a foot or so across. Every fold in and east of town pitches both north and south so as to carry its Heartwellville down and out of sight quickly. At least three folds occur in the Sherman area, two small ones near the county line and the larger one with the marble core exposed. Figure 2.

In the last area to the east, the wrinkles or folds mentioned in the discussion of the marble and Whitingham Schist are repeated in the Heartwellville cover and borders. The ragged or zigzag outcrop on both north and south ends of the area mean folds. Where the formation penetrates (on the map) the Whitingham area there is a syncline, and where tongues lead out into the Readsboro there are anticlines. On the extreme southeast corner of this large area is a small anticline in the Heartwellville high enough to bring out the Whitingham, but not so high as to expose the Sherman marble. Each of these folds pitches and runs under both north and south. And the whole group of folds is contained in one large anticline whose Heartwellville formation spans at the surface one and one-fourth miles. The structure is so steeply pitching that its whole length as shown by this formation is not more than one and one-half miles. Of course it is longer in the Readsboro and even in this formation below the surface.

Judging from the samples of the Heartwellville structure we have, and from those in the overlying Readsboro where the former is covered, the Heartwellville is everywhere intricately folded and plicated into small and large pitching synclines and anticlines.

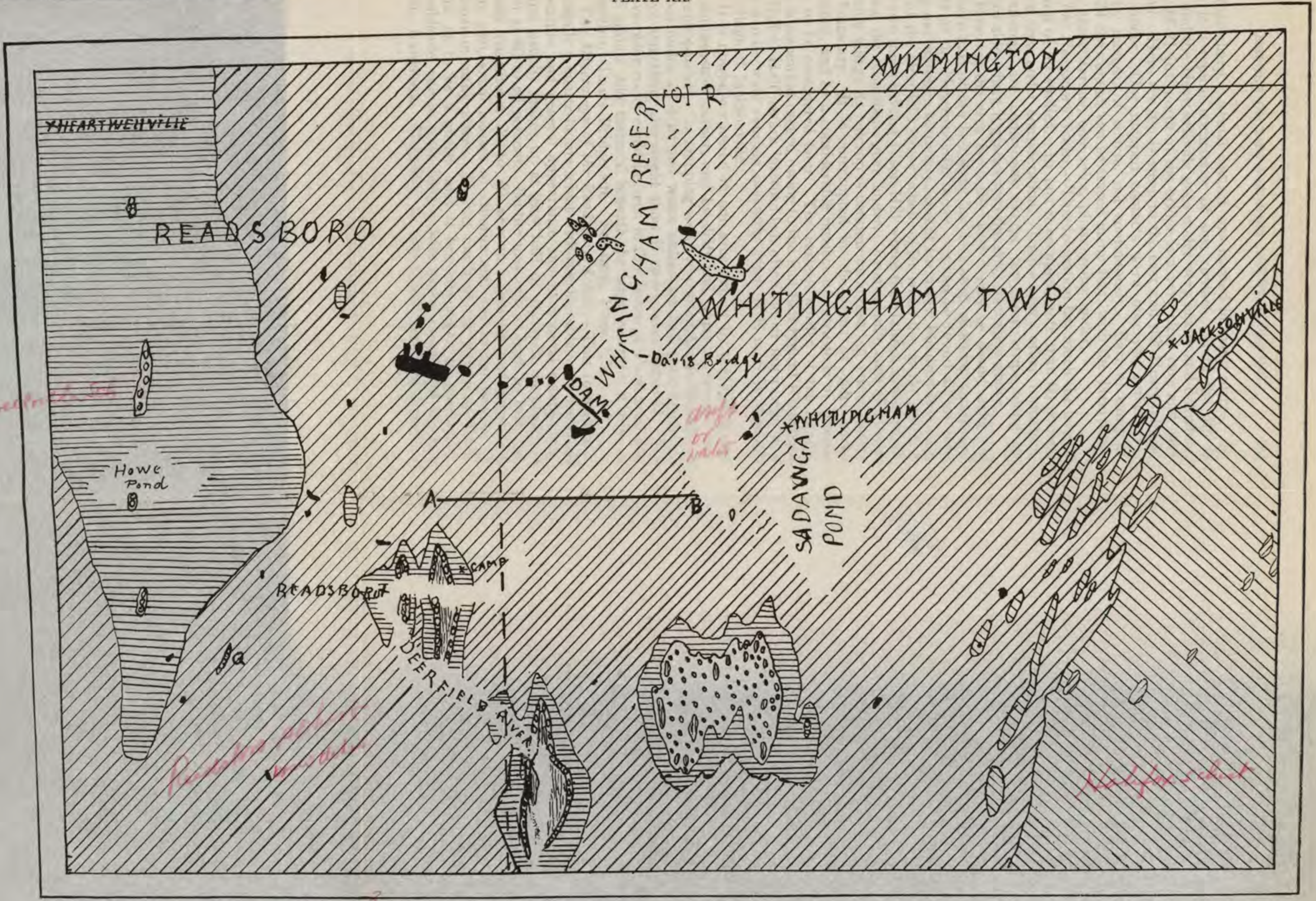
No faults of mention were found in it, and the dikes cutting it will be discussed later under igneous rocks. As stated under Whitingham the contact at the base of Heartwellville is a transition zone, but at the top the boundary between it and Readsboro part, if there were no wrinkling, one would readily estimate 3,000 feet, but there is no possibility of the thickness being half as great as that, for on each flank of the large anticline are several folds from a few feet to a few hundred feet wide. Probably 1,000 to 1,200 feet is thickness enough to ascribe to the formation anywhere in the area.

This formation lies in a large anticline in the western part and several smaller ones in the central part and each fold has wide, broadening a little perhaps northward. This area does not smaller folds all over its back. The smaller folds have wrinkles of a few feet in width all through their structures. The large anticline in the west pitches sharply southward so as to carry the whole formation down out of sight beneath the Readsboro a mile from the edge of our area. In the town of Readsboro and eastward beyond camp, fold after fold occurs. Four or five are known, the largest lying farthest east and sending its eastern limb down below Readsboro schist just east of camp. These folds like those on the big anticline in the west are adorned with smaller folds and wrinkles down to a foot or so across. Every fold in and east of town pitches both north and south so as to carry its Heartwellville down and out of sight quickly. At least three folds occur in the Sherman area, two small ones near the county line and the larger one with the marble core exposed. Figure 2.

In the last area to the east, the wrinkles or folds mentioned in the discussion of the marble and Whitingham Schist are repeated in the Heartwellville cover and borders. The ragged or zigzag outcrop on both north and south ends of the area mean folds. Where the formation penetrates (on the map) the Whitingham area there is a syncline, and where tongues lead out into the Readsboro there are anticlines. On the extreme southeast corner of this large area is a small anticline in the Heartwellville high enough to bring out the Whitingham, but not so high as to expose the Sherman marble. Each of these folds pitches and runs under both north and south. And the whole group of folds is contained in one large anticline whose Heartwellville formation spans at the surface one and one-fourth miles. The structure is so steeply pitching that its whole length as shown by this formation is not more than one and one-half miles. Of course it is longer in the Readsboro and even in this formation below the surface.

Judging from the samples of the Heartwellville structure we have, and from those in the overlying Readsboro where the former is covered, the Heartwellville is everywhere intricately folded and plicated into small and large pitching synclines and anticlines.

No faults of mention were found in it, and the dikes cutting it will be discussed later under igneous rocks. As stated under Whitingham the contact at the base of Heartwellville is a transition zone, but at the top the boundary between it and Readsboro



Geologic map. North line is parallel of 42° 50′ N. West line is meridian of 73° W. South line is Mass.-Vt. state line. East line is Whitingham-Halifax township line. Last two do not run on cardinal directions. Symbols: Vertical ruling = Sherman marble; circles = Whitingham schist; horizontal ruling = Heartwellville schist; oblique NE-SW = Readsboro schist; oblique NW-SE = Halifax schist. Black = basic dikes diorite; Dots = acid dikes; Q = large quartz dike; White = drift or water covered, partly Deerfield valley.

is rather sharp. Actual contact was located in many places. In O-26 is a typical occurrence of this contact. Here the dip is west and the Heartwellville goes under very neatly and definitely. At L-M-21 just north of the bridge is a very clear case and easy to find. Here the dip is steep to the east and the Heartwellville goes under. Our mapped contacts were observed rather frequently though, of course, not continuously. East of camp in S-T-24 the contact can be traced many feet, with the Heartwellville, garnetiferous, blue mica, phase going under.

The Readsboro Schist.—This formation has much the largest outcrop of all studied. In fact it occupies more than 60 percent of the area under consideration. Unlike every other formation, its outcrops are continuous except for some strips along its eastern side where it grades into the next formation above.

Entering the area from the west it may be found along the southern half of our boundary line in a strip widening southward as far as the Heartwellville shows. It can be found all the way along our southern boundary, except for a few hundred feet each side of the Deerfield River, where older rocks are at the surface, until two miles beyond Jilson Hill where the Halifax schist comes in, and the Readsboro goes under. From a mile east of Heartwellville village its outcrop is continuous across our entire northern boundary. It is interrupted by the areas of older rocks described, and by a considerable number of intrusions of igneous rock to be considered later. The eastern border of the Readsboro is somewhat ragged owing to the fact that typical Readsboro and typical Halifax are interbedded, often rather intricately, in a strip a mile wide running obliquely from N-E to S-W through the village of Jacksonville.

It is nowhere covered in our area except by the Halifax in our southeastern corner, and by drift and water in several considerable patches. In mapping we have continued the Readsboro symbol under all drift and water unless we had good reason to believe something else might show if cover were removed. We believe older rocks could be seen in the Sadawga Pond area and more granite dike material beneath the large reservoir a mile or so north of Davis Bridge site. See map, Plate XX.

The Mineralogy of the Readsboro Schist.—This formation is essentially a quartz-biotite schist with considerable variation, both in texture and general appearance and in mineral composition. Quartz usually makes up at least half of the rock, in places as much as 80 to 85 percent. Biotite may run as high as half, but usually constitutes 25 to 40 percent. Sericite and muscovite occur also, small masses of chlorite and one to ten percent of feldspar in many places. In fact much of the rock is so feldspathic as to be a gneiss, and it becomes more so northward. Hornblende, and in some beds, calcite make up most of the rest of the formation. Magnetite in tiny black specks, scattered or in bunches is common, but constitutes less than one percent. Few garnets, tourmaline, and pyrite crystals were noted. Garnets were found at Q-23 in a pasture in a rather typical phase of Readsboro and again near the railroad station as noted below, possibly in a few other places, but they are rare in this formation. These two occurrences may well be in the same beds in a low horizon.

Tourmaline and pyrite in the Readsboro are usually associated with intrusions and will be described under that heading and as a result of mineralization.

Near the base in square N-21 a mile northwest of Readsboro an even grained, gray, feebly banded sample was taken with the following estimated percents of minerals: Quartz 54, biotite 25, muscovite 10, calcite 10, miscellaneous 1. Fragments effervesced freely in many places in cold hydrochloric acid. A little farther east up the hill between the roads, S-21, but probably not much higher stratigraphically for it is right on the axis of the fold, the gray-green rock splits very evenly and readily, is much more siliceous, has about two percent biotite, and 12 percent silvery to green sericite with no calcite. The biotite is in tiny black specks. At W-24, probably a little higher stratigraphically, the formation is gneissic in appearance. Quartz and biotite are about equally abundant, calcite about 5 percent, feldspar and sericite 1 or 2 percent each. Calcite, according to the acid test, is usually absent, not more than one sample in 6 to 8 effervescing at all even hot.

At Q-26, on the nose of the hill east of Readsboro, hence just above the Readsboro railroad station, occurs a large exposure of this formation. It dips steeply westward and is on the flank of the first anticline crossing the hill. The Heartwellville outcrops a very short distance west and less than 500 feet east, hence this must be near the base of the formation yet not nearer probably than 200 feet. It shows also in the stream bed below the dam. It is here composed almost wholly of quartz and biotite about half and half with a small percentage of muscovite and garnet. Perhaps the most conspicuous feature of this exposure is the very good cleavage. It probably is nearly along bedding planes, hence is more due to mica layers than to pressure. The grain here is even and the color a uniform gray. It is one of the most valuable phases of the Readsboro.

A group of beds very similar to this shows in the railroad cut near the curve a mile upstream. In the latter, muscovite prevails over biotite.

At q-27, q-18, and s-t-11 samples were taken. They are still some distance from the top, but higher than any others described. The first is gneissic and massive, dark colored and crumpled a little. Its minerals are estimated as follows: Quartz 50 percent, biotite both black and brown 42 percent, muscovite 6 percent, chlorite 1 percent. At the second the rock is much more distinctly banded, splits better and contains quartz 65 percent, biotite 12 percent, green to silvery soft sericite 20 percent, and feldspar 2 percent. The third sample, still on about the same horizon, for the strike here runs northeast, resembles the last but splits even better. It seems to be about half and half quartz and biotite, with 1 or 2 percent of feldspar and a similar amount of tiny crystals of black iridescent magnetite. No igneous rock was found near, but that does not preclude the possibility of its presence just under cover to aid in developing the magnetite.

At p-27, certainly a little lower than q-27, for the dip is east all the way between, the rock is lighter than at q-27, more gneissic and carries about 80 percent quartz, 10 percent biotite, 5 percent muscovite and greenish sericite, 2 percent hornblende, and 1 percent of chlorite. There seems to be no systematic gradation in the amounts of quartz and biotite, but the calcite is apparently confined to the lower part and the rare feldspar is higher up. Because of the multitudes of small folds it is practically impossible in most places to tell just where one is stratigraphically.

At q-21 the rock is even grained, light and dark banded, and has about average composition, but contains much magnetite, estimated at 10 percent, in beautiful iridescent crystals of varying sizes from one-eighth of an inch down. There is noted here also 2 percent of feldspar. The magnetite is coarser grained and more abundant in the lighter more siliceous layers. A quartz dike cuts through the Readsboro in this square and is no doubt in part responsible for this magnetite, for the latter becomes more abundant toward the dike and occurs freely in it.

At k-4 there is an outcrop of a blue sericite schist very much like the typical blue schist of the upper Heartwellville. When first discovered this rock was mapped as belonging to that formation, but its true relations were later deciphered and it is known to be a layer 20 to 40 feet thick in the Readsboro. It was traced through three squares in the direction of the local strike N. 30° to 35° E. and found to be both overlain and underlain by true Readsboro. It dips consistently northwestward with the adjacent beds and can undoubtedly be accepted as simply a bed in the local formation. This bed, however, so closely resembles the Heartwellville that it carries about 1 percent of black tourmaline prisms and twice as much of garnet, some crystals of which are nearly one-half inch in diameter.

At O-7-8 a very similar occurrence is found. The amount of quartz is a little larger and garnets were not recognized, but the rich iron stain and the chlorite may be the remains of the garnet. Here typical Readsboro was found both above and below and the thickness of the blue rock was not over 25 feet. The whole structure dips eastward and the same beds were seen on ground 200 feet lower and 800 feet farther east in striking ledges.

Here again true Readsboro is both above and below. It should be noted in this connection that the patch of Heartwellville mapped in N-O-11-12 is an anticlinal structure and the blue schist dips both east and west on opposite sides.

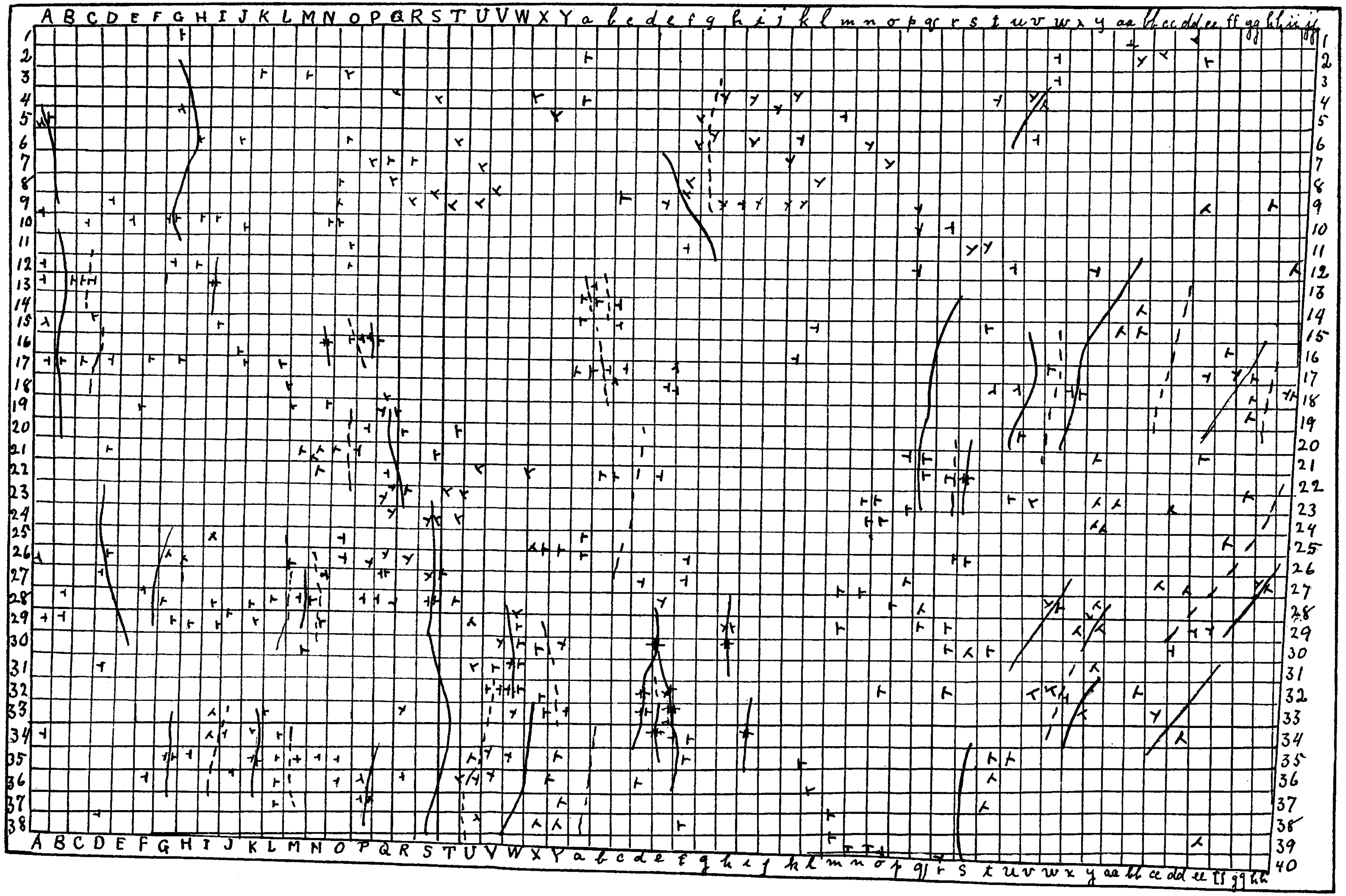
It seems to us as we look the whole problem over that the Heartwellville-like layer 20 to 40 feet thick stands for a reversion to true Heartwellville sedimentation after several hundred feet of Readsboro had accumulated.

Another phase of the Readsboro which needs description is known as the "pebbled" rock. At a short distance it looks like a conglomerate when weathered a little, and like a banded porphyry when fresh. The layer has been seen in several places and is believed to be about 600 to 700 feet above the base of the formation. This determination has been made above the Sherman marble to the east up the hill where the pebbled phase occurs nearly at the top of the steep slope and almost on the state line, perhaps a half mile back from the river, also along the river a mile above Readsboro. The rock consists of biotite, quartz and a little feldspar. The biotite is arranged in wavy layers and the other light colored minerals in knots between the mica layers (figure 3). Thus the dark mica surrounds the nodules of quartz and feldspar. On weathering, the harder quartz stands out a little in relief. The probable thickness of these layers is 30 to 50 feet.

It has been impossible to arrive at any concise measurement of the Readsboro, but estimates in various places have been made. In the hill tunneled through from the big Whitingham dam to the power plant, a continuous east dip is found from the river almost to the very summit. This is a horizontal distance of a mile. The succeeding formation is not preserved on the hill, hence the whole hillside is Readsboro. If the layers were horizontal through the hill there would be 950 feet in thickness; but they dip into the hill at an angle of 30° to 35°, which would give a thickness of about 4,000 feet. How much Readsboro has been eroded from the top of the hill cannot be known. How much Readsboro goes down in east dips on the east flank of the anticline and west of the river, cannot be accurately known, and also how much is repeated by minor folds is not known. But the east dips over the whole stretch from the crest of the camp anticline to the top of the tunnel hill are very constant and very few, even minor wrinkles are known. Hence it seems perfectly safe to assume that there are at least 4,000, possible 6,000, feet here (figure 4).

The dips are similarly constant and eastward for a mile on the east slope of Jilson Hill. Here the beds go down at an angle of about 30° to 40° for more than a mile horizontal, which would give a thickness of 4,000 to 5,000 feet. Few wrinkles occur here to complicate the problem. We believe, therefore, that

PLATE XXI.



Represents area mapped, ruled in small rectangles each square was one-sixth inch = (one-sixth mile) in note books. All references in text to localities by coordinates, can be located on this grid; dips and strikes are shown. Solid lines among symbols indicate anticlines, dash lines indicate synclines. The main large structure does not show on this grid. Read with geologic and topographic maps.

a thickness of 4,000 for the Readsboro is reasonably safe. We have no evidence that it varies greatly in thickness from place to place, except as it has been removed in places more or less completely by erosion. It is probably not all present except at such places as it goes under the Halifax, the next younger formation.

Structure of the Readsboro.—In as much as the Readsboro outcrops all round the camp marble area with its Whitingham and Heartwellville, it certainly has an anticlinal structure here. In a similar way it surrounds the marble areas as a whole upon the hills east of Sherman, witnessing to an anticlinal structure there. In the high hill between Readsboro and Whitingham through which the power tunnel pierces the structure, it is distinctly synclinal, but the syncline is shallow and, emerging on the south end of the hill at the road, almost runs out east of the power plant. At the north end of the hill the axis of the syncline bears westward and rises and then passes into several small synclines and anticlines on north of Davis Bridge site. Thus in the hill one broad syncline with some lesser wrinkles dominates the structure for a width of nearly two miles, but at both ends the trough comes up and frays out into a group of lesser folds. Along the flanks of this larger syncline the strikes converge southward in the southern half, and northward in the northern half.

In the area north of Readsboro for two miles the structure consists of a series of small folds both up and down, the strikes are convergent and divergent in alternating succession. Thus we may interpret the folds as pitching. This pitching is often steep, carrying a whole structure down in less distance than a mile. This is strikingly shown in the borders of the Whitingham marble area. Southwest of Readsboro the main structure is synclinal, but in it are several lesser pitching synclines and anticlines. More than that, a structure starts down as a pitching anticline, weakening as it goes and gradually becomes very small, and then a syncline begins on the crest of the anticline and increases in size while the latter continues to fade out. Soon the axis is distinctly that of a syncline and the reverse structure has disappeared. This type of transformation was elusive and distressingly confusing until we really saw what was happening. Then their pursuit became fascinating. Nearly every structure we worked was of the pitching sort, wide in its central part and tapering at both ends, and in scores of cases we proved the change from one structure to the opposite along the axis.

Not only are there such structures with dimensions of thousands of feet, but there are many of tens of feet all over the backs of the larger anticlines and in the synclines, and again the strata in these lesser structures are plicated in a much more minute but identical pattern so that one can gather hand specimens of one or two feet length in which two anticlines at one end and a syncline between, become two synclines at the other with an anticline between. The plications are not always simple and schematic, but in places are most intricately contorted and twisted. In the borders of Whitingham village, northwestern part, one can see some beautiful illustrations of these quirks.

Many dikes of several kinds occur in the Readsboro which will be discussed in a later section.

The Readsboro has a pretty definite boundary with the Heartwellville below and very little interbedding near the contact, but that between the Readsboro and the Halifax above is of an entirely different character. These two schists are distinctly different, one is gray, the other black to dark green, one highly siliceous, the other rarely siliceous, one resistant and the other crumbling and easily disintegrating. But over a strip a mile or more in width along their mutual boundary the two are usually thoroughly interbedded.

At Jacksonville, for example, green chlorite schist of the Halifax type occurs west of town and gray siliceous rock of the Readsboro type occurs almost a mile southeast of town. In the hills one and a half miles southwest of town, six beds of chlorite schist 100 to 600 feet thick alternate with as many, and as great, beds of typical Readsboro. Another mile southwest five lenses of Halifax occur in otherwise solid Readsboro, while three miles northeast of Jacksonville, on the Halifax-Marlboro township line and just beyond the road leading south to West Halifax five lenses of Readsboro occur in typical Halifax schist. The latter type is almost continuous for a half mile west of these lenses. Each lens is 100 to 300 feet wide and one-fourth to three-fourths mile long. This illustration is entirely outside the area shown on the map. Besides such larger interbedding as this described there are many short, slender lenses of each kind in the other. The transition is never by easy gradations, but by alternations of the two kinds with each type becoming rarer away from its main area as the other becomes more abundant until the change is complete.

The Halifax Chlorite Schist.—The chlorite schist occurs in the eastern part of our area with a strike of NN-E-SS-W. In the southern part, along the state line it has a breadth of over two miles, but its strike is such that in the northern part it runs off the map east and does not cross our north line at all. Thus it may be said to have in our area a right triangular shape with base on the south of two and three-fourths miles, long limb on east of six miles and hypotenuse running through Jacksonville. This shape has no relation to the structure. The dips are consistently eastward, though locally reversed, and the strike is true N. 25° to 30° E., which corresponds roughly with the hypotenuse of our triangular area.

Since the Halifax is the youngest formation and the Readsboro dips eastward under it all along their mutual contact, it can nowhere be covered with bed rock.

Scores of outcrops occur on hills, ridges, in road cuts and, occasionally, in stream beds. While it is not very resistant, its waste, mostly mica, is easily washed away and outcrops are frequent. Drift and meager products of its own decay mantle it most of the way, but probably rarely deeply.

Its mineralogy is generally simple. Dark green chlorite is the characteristic mineral. The samples discussed here show the similarity of the formation, whether well into the chlorite or well into the Readsboro. At s-30 beside the road nearly two and one-half miles southeast of Whitingham and almost a mile on the Readsboro schist side of the mean boundary between it and the Halifax, the rock is estimated to contain 75 percent chlorite and 25 percent quartz, all fine, even grained, the chlorite usually in tiny prisms. At w-32 near the border and almost a mile from the last, the estimated constituents are chlorite 80 to 85 percent in prisms, quartz 10 to 15 percent fine, even grained and straight, even bedding. At d-20 in the border but possibly nearer Halifax than Readsboro schist, one mile straight south of Jacksonville, the minerals are chlorite 84 percent in prisms and plates, quartz 15 percent with the same fine, even grain.

At cc-27 a half mile into the Halifax the rock is crumpled sharply and is in line with the disturbance east of Jacksonville. Minerals are chlorite about 90 percent, with quartz about 9 percent. Rock is just as fine, even grained as any.

At jj-25 one and one-half miles into the Halifax and about two miles down valley from Jacksonville, two samples were taken. One is estimated at quartz 50 percent, hornblende 5 percent, chlorite 40 percent, garnet 1 percent; the other, quartz 50 percent, sericite 45 percent, chlorite 4 percent. The chlorite is coarser than usual and the sericite is quite coarse with white to shiny silvery color.

A band in part richer in hornblende, but probably the same horizon, occurs in w-32 in the midst of the interbedded material. Two samples taken are estimated as follows: No. 1, hornblende, mostly in rosettes, with slender crystals often one inch long, 10 percent, garnets 1 percent, quartz 60 percent, sericite 25 percent, other micas 2 percent; No. 2, hornblende 30 percent, quartz 40 percent, garnets 1 percent, feldspar 3 percent, chlorite 25 percent. The former is coarse grained, the latter fine, even, and nicely bedded.

A similar band of hornblende schist occurs at ee-25 near the top of the ridge, but a few feet down on the east side. This is believed to be the same bed as the one described in previous paragraphs from jj-25 and from w-32. It has a similar strike and dips like them to the southeast, but there is a small fold between them and this occurrence.

Like the lower formations this schist has been shot with igneous material and locally modified, but that matter will be more fully treated under "Igneous Rocks."

The Halifax schist is probably more homogenous and similar over its whole area than some of the older formations. We did not become familiar with the next formation above, which outcrops farther east, and do not know the nature of the contact on that side. We have found variations from the true green chlorite schist in several places east of the line placed as our farthest boundary. Whether they should be separated as a new formation our studies are insufficient to determine. Possibly a small part of the southeast corner of our area merits a new formation name, but we do not feel justified in applying such a name without more study of the succeeding rocks.

The Halifax schist is probably 2,000 to 3,000 feet thick. It may be even more. Its complex structure and similarity in composition make its thickness difficult to estimate and the fact that we are not familiar with its upper contact precludes any positive statement as to its thickness, nor do we know anything of any differences in thickness.

This schist, while dipping generally eastward from a strike of N. 25° to 30° E., is as intricately folded, crumpled, and mashed as any part of the section. A fine, wavy structure occurs extensively in cc-27 and out therefrom along the strike in both directions. The wave crests are one-fourth to one-half inch apart and are not continuous, but run into each other just as such plications have in the older beds. Within six inches of length a fold may run into its neighbor on each side or divide into two and reunite, or change completely from a synclinal wrinkle to an anticline. This minute plication is involved in larger folds of similar pattern, whose dimensions may be 20 to 50 feet in length and 2 to 3 across, and these in turn in still larger folds 200 to 300 feet across and a half mile or so in length.

One larger fold probably overturned, certainly badly confused and mixed up occurs northeast of Jacksonville. As we saw it one end is in the hill one-half mile east of the village and the other end some two miles northeast along the row of hills. The mashing has been severe along this zone. Possibly there is more than local faulting, but we do not think there is more than a few feet of displacement in any one place. There seems to be a number of local slips and the fold seems to be overturned. We reserve, however, a final interpretation of this structure until more field work can be given it. Perhaps the actual conditions cannot be disclosed with the mantle over it as much as at present.

Correlations of the Vermont Section with that of Adjacent Massachusetts.—We are loath to make correlations with the splendid work of Professor B. K. Emerson[1] and others, for in some respects we do not agree. Our work was largely completed before the above bulletin came to our hands and no attempt has been made in the field to correlate. Our mapping was done independently, not one of the party had ever seen Emerson's map of Geology of Massachusetts and Rhode Island until our map was wholly completed. Our petrographic studies, however, have all been gone over with the map in hand. The similarities between our descriptions and those of Mr. Emerson are interesting, the differences often striking. Our interpretations of relative age and succession of rocks and of structures agree very satisfactorily. Our stratigraphic subdivisions are at some little variance, but probably no more than might occur in tracing the several miles between his types and ours.

[1] Emerson, B. K., U. S. G. S., Bull. 597.

We believe, however, that it is best to state just what we have found even if it does not wholly agree with Massachusetts findings, make as accurate correlations as are possible and leave as little confusion as may be, reserving a final correlation to later studies. Probably some of the Massachusetts lines not yet known in Vermont can be traced across into our area, even though we have not succeeded in picking them up, and possibly some of our lines not yet recognized in Massachusetts can be traced across the boundary by starting in Vermont.

Massachusetts Section.		Vermont Section.	
Hawley schist and its hornblendic lenses,	2,300 ft.	We did not go far enough east to find it.	
Savoy schist,	3,300 ft.	Halifax schist,	2,000-3,000 ft.
Chester amphibolite,	400 ft.		
Rowe schist,	4,000 ft.	Readsboro schist,	4,000-6,000 ft.
Hoosac schist,	4,000 ft.		
Greylock schist,	1,500-2,000 ft.	Heartwellville schist,	1,000-1,200 ft.
Bellowspipe limestone,	?	Whitingham schist,	40-100 ft.
		Sherman marble,	600 ft.

By placing our map and Emerson's in juxtaposition, the equivalency of Hoosac in Massachusetts and Readsboro in Vermont is established. In the same way the Savoy and Halifax are equivalent. By position then the Greylock and Heartwellville are essentially equivalent, but our Heartwellville goes below the Readsboro southward in every occurrence before it reaches the Massachusetts line. The Emerson map has nothing corresponding with our Whitingham for the Bellowspipe limestone immediately underlies the Greylock. On the basis of position and character of rock we place our Sherman marble equivalent essentially to Bellowspipe limestone.

Apparently our section omits the Rowe and Chester schist, but we find in our Readsboro, material of a lensy character and not continuous enough to map as separate formations, which on mineralogic grounds might be considered equivalent. Thus the correlation is workably complete.

Some minor differences in mineralogic composition remain to be pointed out. The discussion will take up the formations in order of age, beginning at the bottom with the oldest—Sherman marble.

The Problem of the Sherman Marble.—Since the Sherman immediately underlies the Whitingham and Heartwellville and since the latter is equivalent to the Greylock schist, our Sherman is to be compared with the Bellowspipe limestone. This limestone as described by Dale[1] is "a series of limestone strata and calcareous (sometimes non-calcareous) schists.—In places the rock is quartzite" and Emerson[2] says, "a subordinate, impure limestone which grades (downward) into the Berkshire schist."—It includes the quartzite of Dale. (See reference above.)

Dale continues (p. 148), saying, "the micaceous element frequently predominates, making the rock a calcareous schist and in several localities the calcareous element disappears altogether." This is true of the Sherman in minor lenses, but not in any large bodies. He mentions galena, sphalerite and pyrite; we have the latter. We found none of the beds of gneiss among the calcareous layers as in the Greylock region. Quoting from Wolff, who made microscopic studies of this rock, Dale continues, "a bluish gray, finely crystalline limestone, composed of calcite grains and quartz grains," the Sherman rarely has quartz, but it has more mica than Wolff seems to find. His abundance of graphite is well balanced by our generous crystals and flakes at Sherman. At Greylock the marble contains feldspar, microcline and twinned plagioclose, but without petrographic examination[3] we have been unable to find any feldspar. Wolff reports limonite frequently; we have it but believe it is largely pseudomorphic after pyrite or simply in unorganized masses left after the oxidation of the sulphide.

We have nothing approaching a quartzite, but the limestone from which the Sherman was made must have been impure and even siliceous. The present mineral content points both to aluminous and non-aluminous ingredients. Iron was no doubt present in some beds in addition to the pyrite for both actinolite and phlogopite are now present in the marble. Likewise silica must have been present in the limestone to furnish the acid radical for tremolite and actinolite. It is generally believed that except in contact metamorphism very little material is actually added to sedimentaries in making schists and marbles.[4]

The Identification of the Whitingham.—The equivalency of the Whitingham schist is in more doubt. The fact that it contains calcite in some layers, and that it is interbedded along its contact with the Sherman may be reason for correlating it with the upper part of the Bellowspipe. On another count, however, it seems not to belong with our marble, for it runs some 50 percent quartz (metamorphosed quartz sand grains) and is rich in biotite,

[1] Dale, T. N., Mon. 23, U. S. G. S. (1894), p. 180.
[2] Emerson, B. K., Bull. 597, U. S. G. S. (1917), p. 40.
[3] The microscopic study of the rocks of this area is contemplated, but the sections are not ready yet, hence the work could not be done for this report.
[4] Bastin, E. S., Jour. Geol., Vol. 17 (1909), pp. 445-472.

both of which are rare in the marble. It does not in our area resemble notably either its bed or cover. It seems best in Vermont to map it separately for wherever it should occur it was found and in each case characteristically developed.

There are occasional crystals of white, milky feldspar and this with its calcareous character may be sufficient to establish its relation with the marble. If truly correlated with the Bellowspipe, it represents the more quartzitic and granulitic phases. In the Greylock area the limestone is found to be interbedded with quartzite and to contain stringers of gneiss, but in our Readsboro area the calcareous and siliceous phases are better segregated, the latter occurring mainly above the former. Because our upper part seems so distinctly different in character we believe it should be here mapped separately, the more so that it is not exposed anywhere continuously from our area to the Greylock exposures.

The Problem of the Heartwellville.—The identity of Greylock and Heartwellville schists is well established, both by position, as shown above, and by mineral composition, structure and texture. Dale (Wolff)[1] and Emerson[2] describe the Greylock as a much foliated and crinkled dark mica-quartz schist in which muscovite (sericite), and chlorite predominate, but in which are found locally biotite, magnetite, ilmenite, albite, tourmaline and even calcite in a number of places. Our description agrees well with theirs, except we have not found calcite, save in one place near the top of the Whitingham, even when reasonably fresh material was examined with acid, but we do find garnets widely scattered through the formation and usually of the almandite type.

In Dale's paper, p. 186, is described a feldspathic phase of this schist as "consisting of numerous squarish albite crystals, rarely in simple twins, crowded closely together, but surrounded by interlacing fibers of muscovite, chlorite and biotite with magnetite grains and many tourmaline needles. Quartz occurs rarely, in little grains or aggregates. The biotite and chlorite are often in separate masses, but often pass into one another in the same piece." This description might be applied verbatim to a sample taken at J-31 and occurring in ledges a mile or more northward. The rock could be recognized perfectly from the description of the Massachusetts occurrence.

The Greylock schist is not to be correlated with the Savoy schist as is done by Emerson[3] in his older work and even suggested in the later publication. The structure and the sequence within the structure establish the Savoy as much younger. Al-

[1] Dale, T. N. (Wolff, J. E., petrographer), loc. cit., pp. 186-188.
[2] Emerson, B. K., loc. cit., p. 40.
[3] Emerson, B. K., Monog. 29, U. S. G. S. (1898), p. 18; Bull. 597, U. S. G. S. (1917), p. 40.

though there are some striking local resemblances, such a correlation is clearly impossible by position of strata.

The anticlinal structure so clearly shown on Emerson's map in Monroe and Rowe townships of Franklin County, Massachusetts, is even better evidenced in southern Vermont. It is on the basis of this broad anticline with its opposing dips that the relative ages of the formations are established, and until this structure was delineated no way was known to arrive at the relative ages. When consistent dips on both sides were found all along it, the ideas of isoclinals, and monoclinals, and strike faults were all laid aside. It is this unity and continuity of structure in the Vermont and Massachusetts rocks which helps to secure the correlations made above and yet to be made.

Further Dale (p. 188) speaks of numerous folds (obviously small because all in so small a space) sometimes compressed and overturned, also of thickening of layers in consequence of plications, and of a coarsely foliated and a wavy structure. All these terms apply admirably to the Heartwellville of the Readsboro vicinity. The minute and gross plications and also the small and large anticlines and synclines of our area seem to be repeated in the Greylock area.

The estimates of thickness are remarkably close together considering the condition of the rock.

The Equivalents of the Readsboro.—As already suggested, on grounds of position the Readsboro corresponds best with the Hoosac schist, but we seem also to have included in our Readsboro the Rowe schist and Chester amphibolite. Let us consider the Hoosac first. The Readsboro might well be called a gneiss or at least a felspathic schist, and this becomes more and more true northward even beyond our area. Emerson[1] quotes earlier workers in both Massachusetts and Vermont to the effect that the formation in question becomes schistlike as the state line (Mass.-Vt.) is reached from each side, the formation being clearly gneiss in southern Massachusetts and north from Readsboro to Wilmington in Vermont, but decidedly a schist on the Massachusetts side of the line.

An earlier statement bearing on our incorporation of Rowe and Chester in the Readsboro is found in Emerson's Old Hampshire County, p. 69. "The Hoosac is here (on the road, Monroe to Rowe, Mass.) a dark sub-porphyritic, gneissoid biotite-mica schist. Farther on it swings round to run N. 20° E. and dips 20° E. and crosses the town line with the most westerly of the roads from Rowe to Vermont, far to the west of the point where, upon the Vermont map the corresponding boundary is made to cross the state line." Obviously some mapper of Vermont geology may rejoice in our delineation of the Vermont top of the Readsboro.

[1] Emerson, B. K., Mon. 29, U. S. G. S., pp. 67-68.

PLATE XXII.

Bouldery stream bed of West Branch Deerfield River a mile or two above Readsboro. Note rock wall on right and great boulders in the channel. A youthful stream.

We find the Readsboro in Wilmington township fully as feldspathic as the Hoosac is found to be in Massachusetts south of the schist phase near the state boundary, and somewhat feldspathic even around Readsboro. We find in the literature no mention of calcite in the Hoosac except that quoted by Emerson[1] from an old Vermont state report, which says, "In Whitingham and Readsboro there is a large amount of dolomite and saccharoid limestone present in the gneiss in the form of beds." We have shown in previous pages that these beds all belong to the Sherman marble, at least two formations below the Hoosac or Readsboro. We have found, however, a few small calcite crystals in the formation at scattered places even farther north than either of the towns mentioned and up to 10 percent in N-21 north of Readsboro.

According to Dale[2] and Emerson[3] the Rowe schist is a monotonous, pale green, or light gray hydromica schist; both call it quartzose, magnetitic and chloritic. This composition agrees well with the Readsboro. We described the formation frequently as gray-green. Because of these many similarities we could not find grounds in Vermont for subdividing, so drew no line corresponding with that in Massachusetts between Rowe and Readsboro schists.

Emerson[4] points out that his Massachusetts section, Hoosac to Hawley schists, is continuous and conformable. This section runs from our base of Readsboro beyond our area eastward. We agree that these beds are wholly conformable. Moreover, we found the three beds below this section wholly conformable among themselves and with the Readsboro above. Therefore, we cannot agree with Emerson[5] where he says, "the Chester amphibolite occupies about the position of the Bellowspipe limestone and may be its time equivalent." No doubt the problem looks quite different in the Vermont setting from what it does in the Massachusetts surroundings. This Chester amphibolite should reach into our area about where West Branch Brook flows out, *i. e.*, a mile east of Jilson Hill or two and one-half miles west of the Halifax-Whitingham township line. We have mapped typical Readsboro a half mile farther east than this place and feel pretty sure of our ground from the Vermont side. We have found lenses and narrow strips, however, of hornblende schist in many places interbedded with the Readsboro in this vicinity. We also recognized the same lensy, interbedding in Hogback Mountain and Higley Hill and vicinity 8 to 11 miles north-northeast of the Massachusetts state boundary, in Whitingham township. We considered the igneous origin for these beds, but found no sufficient criteria for settling the point that way. Some Massa-

[1] Emerson, B. K., Mon. 29, U. S. G. S., p. 68.
[2] Dale, T. N., Bull. 597, U. S. G. S., p. 41.
[3] Emerson, B. K., Mon. 29, U. S. G. S., p. 76.
[4] Loc. cit., p. 78.
[5] Emerson, B. K., Bull. 597, U. S. G. S., p. 41.

chusetts workers have suggested that these beds were "ferruginous or perhaps tufaceous deposits without the influence of granite." We preferred to call them dioritic dikes at first, but have come back so far as our Vermont evidence is concerned to the sedimentary origin. We have found no emery nor serpentine nor rock from which serpentine might readily be derived, hence in our area have no need to explain by igneous intrusion nor by tufaceous surface eruptions. We, therefore, included the whole section eastward to the chlorite schist all in the Readsboro, and see in it considerable variation in the character of the sedimentation, but no igneous activity. This, of course, throws out no barriers to the igneous interpretation for the extensive, interesting and valuable emery and serpentine bodies in Massachusetts. They may indeed well be considered basic intrusions in the Readsboro or its equivalent (in part) the Rowe—intrusions not extending into Vermont in these horizons.

We have several kinds of hornblende schist in the eastern part of our Readsboro. Some beds are mostly feldspar and hornblende and these tempted us most to use the igneous origin for them; some are sericite, hornblende and quartz with the hornblende scattered in bars or bunched in pretty rosettes. These we were sure were of sedimentary origin.

The Halifax Equivalent.—By placing the maps together again we find our Halifax matched up so far as we have worked it with the Savoy schist of the Massachusetts map. There is no break in our succession and none in the Massachusetts section, hence structurally the two units seem also to be equivalent. But mineralogically according to our descriptions and those of Emerson they are very dissimilar. It seems probable that we have not done enough work in the narrow wedge we have called Halifax schist. It was the last formation reached, it was not crossed completely, in enough places to know its upper limits, and owing to the fact that weeks, not area, limited our operations we did not master this formation. May we, therefore, be permitted to drop the correlation here and take it up at this point at a later date?

We found no means in our area of ascertaining the age of any of our formations. No fossils with the exception of certain structures of possible organic origin in the Sherman marble at Sherman were found. Our succession of rocks is short and conformable throughout so far as we could find. We have shown the probable equivalency with the Massachusetts series and Professor Emerson ascribes all the formations with which we have correlated, to the Ordovician. There seems to be no reason to question this decision. Therefore, we will consider our whole section as belonging to the Ordovician system. There seems to be good reason for considering it to be the larger part too of the Ordovician as exhibited in southern Vermont.

IGNEOUS ROCKS.

General.—Igneous rocks are only in small dikes and stringers in this area. No lava flows, surface eruptions or even tufa deposits were recognized. However, igneous rocks are widespread both in time and space and intruded into every formation. Further they vary considerably in character and are so interrelated that their relative ages are perfectly clear.

There are four distinct types of rocks grouped into two divisions as follows:

- Basic dikes.
  - Biotite dikes.
  - Diorite dikes.
- Acid dikes.
  - Granite Dikes.
  - Quartz and quartz-feldspar dikes and stringers.

Biotite Dikes.—This material was first seen a mile and a half northeast of Wilmington in the hills on the east side of North Branch Deerfield River. At this point it was almost pure biotite. This occurrence not being in the area now before us, similar occurrences farther south will be noted.

Dikes of this type were found at S-20, V-31, M-21, L-25, Q-15, D-31, q-21, q-27, e-9, and e-18. These are all in the Readsboro, with the exception of D-31, which is in Heartwellville. They are so dark that they would be difficult to discover, in either the Heartwellville or the Halifax. They may occur as frequently in both, but were not recognized if they do. While dark to black biotite is the dominant mineral in every occurrence, quartz (5 to 10 percent) is present, and at e-18 constitutes 15 to 20 percent. Quartz is always clear to slightly milky. Feldspar makes up 1 to 2 percent of the rock, and calcite was found abundantly at Q-15, and in small quantities at V-31 and S-20. No magnetite was found except at Q-15, although every specimen taken was crushed and tested. Pyrite was found at S-20 both fresh and limonitic. Limonite was found in most places and is reckoned as secondary by oxidation of pyrite. No other mineral of the Readsboro or Heartwellville was recognized in this rock.

Variations from place to place were slight. Such differences in composition as suggested above were all that were noted. The rock is remarkably constant. It is always very dark in color, some localities show it a little more gray than others because of the larger percentage of quartz. Texture is even, fine, and distinctly schistose and foliated in every occurrence.

That the material is of igneous origin and not a local phase of the Readsboro is established by its relation to the latter. First, it is obvious, as will be shown later, that the Readsboro is of sedimentary origin. This fact was stated and maintained by the workers in Massachusetts years ago. Second, the biotite dikes interpenetrate the Readsboro in every direction in slender stringers and sheets, in bodies that thicken and thin as they pass from layer to layer, in lenses, and all connected up in any given area. Third, while never as thoroughly metamorphosed as the Readsboro, it always shows much schistosity and foliation, always coincident with that of the Readsboro. This point further suggests that the intrusions were made about the time of the metamorphism. If earlier then the metamorphism should be of the same order, if later, it should not be changed so thoroughly and need not have the same schistosity. No other igneous material in any part of our area shows any such degree of transformation.

The bodies of this rock are usually small, stringers are but fractions of an inch in thickness. Lenses and dikes proper are rarely more than a foot or two through. The thickest is probably at M-21, where the intrusion was traced for 200 to 300 feet with a thickness of 10 feet more or less. At S-20 nothing more than 6 or 7 inches thick was seen, although here is a rather extensive network of branching stringers, lenses and sills penetrating the Readsboro in every direction, both with reference to the compass and the bedding. At e-18 the mica dike is large and follows bedding of Readsboro remarkably well.

These dikes seem never to have mineralized the country rocks at all. No difference was ever noted along the contacts, but usually the boundaries were as sharp as could be expected after both rocks had been metamorphosed to schistosity.

There is no inclination on the part of any of us to consider any two of these occurrences connected, at least on the present surface. No statement can be made as to connections down below. Proximity and similarity of rock would certainly suggest probable unity of source for the materials.

Diorite Dikes.—Much more frequent are the dikes of diorite. They are widely scattered also over the area, are larger, and have given the impression of being much more connected into systems of dikes. Many occurrences are minute, so small that no attempt was made to map them, others are large and more or less continuous for hundreds of feet. Some dikes so far as we know are single, others are branching and even include blocks of the country rock. The diorite dikes, often called green dikes, are more frequently known in the Readsboro, but they occur in the Heartwellville in F-28 and in the Halifax at s-32. The dike here is described as very typical. It is associated with chlorite schist and the chlorite is a lens in typical Readsboro. These dark dikes are difficult to see in dark formations and probably were often passed unnoticed.

The largest occurrences found were about two miles north of Readsboro between the two roads. Plate XX. Many boulders were found on the fences and in the fields for a mile south of these rocks, pointing clearly to a large source near. While careful and repeated search failed to discover connections

between all the outcrops found in this vicinity, we believe if the drift and waste were removed much more continuity would be seen than the map shows. The main mass is probably 500 feet wide and is known at the east road in the garden, and about the fence in S-T-15. Continuous exposures were found westward up the hill almost to the west road through squares R-15 and Q-15. Large stringers lead off to the north from this mass and have been traced in that direction almost to the road. On the road in squares R-13, P-13 and O-12-13 the dike is known, but its absolute continuity could not be proven. On the south slope of the hill in O-12 it is known and at the center of M-N-11-12 is a large area of the rock. East from the main mass through squares T-15 and V-15-16 are outcrops and great boulders in abundance, but connections could not be found. At Y-15-16 above the west end of the big new dam, other extensive masses were found 400 to 500 feet across with both contacts against Readsboro exposed, yet no connection with other areas could be traced for, as usual, drift and other mantle cover the rock. Across the river southeastward and near the dam are many boulders and several unquestioned outcrops. Along the switchback railroad tracks good exposures can be seen of beds of diorite thrust into the Readsboro almost in a horizontal position. Some of these are very badly decayed, showing what weathering does for the rock. It is no wonder boulders do not occur far from their parent ledges if these exposures give a fair sample of the weathering of the diorite dike.

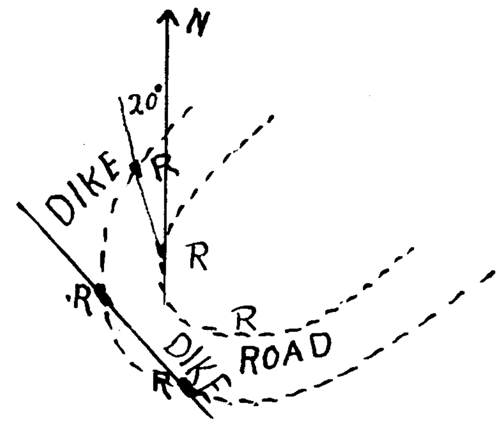


FIGURE 5. Diorite dike in Readsboro schist (R) near east end of big Whitingham dam (b-18). One side of dike trends N 20° W, other side N 45° W at places where seen. Exposures at thickened places on lines. Dike crosses road at the curve.

This dike could not be or was not traced over the hill eastward from the dam, but was found at e-19 and f-18 and again a half mile farther east at the fork in the roads, i-18-19. No patches farther east are known that might be connected, but if all these occurrences from M-10 to i-19 are parts of one great dike with several stringers, the total length is over three and one-half miles. There seems little doubt but this series of outcrops is one. No other such series in our area is known, but northeast of Wilmington a similar dike was actually traced over two miles.

Northwest of Whitingham, i-11-12, one and one-fourth to one and one-half miles extending north and south for about a half a mile, was found a green diorite dike of this same sort. This one has considerable interest because it is intersected and completely parted by a granite dike about 300 feet wide, thus establishing the relatively greater age of the diorite. Other scattered occurrences of diorite dike are known at K-25 and at K-29, J-34, O-17, P-Q-18, P-23, T-23-24, L-M-21-22, W-31-32, near the new large power plant, N-32, F-30, S-10, X-10, c-10, s-30, n-32, f-9, beginning almost at the water's edge in the large reservoir and leading in two stringers a long ways up the hill, and finally at t-u-27 and westward where a line of outcrop probably marks a continuous dike.

That these dikes seem essentially to be limited to the Readsboro does not prove anything save their greater visibility in that formation. Those at the surface in the Readsboro in the western part of the area have undoubtedly come up through the other formations studied and when the Readsboro shall have been eroded away over its present outcrop then the dikes will be at the surface in the older formations. And the dikes outcropping in the eastern part of the Readsboro no doubt came up into the Halifax, probably through it and have been eroded down with the Halifax to their present levels. There is no reason why they should not occur as freely in one formation as in another. They may occur more frequently in the central part of the great anticline, than out on its flanks or even in bordering synclines. The large dikes north of Readsboro might bear out this suggestion. It is true also that the large granite dikes to be described presently are near the axis. They too, however, must have come up through the other formations and now occur only in the Readsboro by an accident of time and stage of erosion.

Mineralogy of the Diorite Dikes.—In 1922 a paper on mineralization along the dikes of southern Vermont was prepared[1] as a minor study in our field work of 1920. Since this paper deals with exactly the same problems as those of the Readsboro region, free use will be made of it in the succeeding pages.

These authors point out that the diorite dikes are typically nearly 70 percent hornblende, with about 30 percent quartz and feldspar in varying proportions, and with pyrite or magnetite in small amounts. The range of ratio of the essential minerals is

[1] Bray, Miss Harriet G. and Emery, Alden H., Ohio Jour. Sci., Vol. 23 (1923), pp. 83-88.

from 50-50 to 80-20 with every gradation between. The rock is generally fine, even grained, with the feldspar and quartz arranged in spheres or circles scattered more or less uniformly through the rock. In places these bunches are almost indiscernible without the petrographic microscope. In rare cases the centers of these lighter colored spheres are empty, but they generally contain biotite, magnetite and pyrite with limonite pseudomorphs after pyrite and very perfect hornblende crystals.

In a specimen where biotite occurred in the center of the sphere a microscopic study showed a zonal arrangement of the two minerals. The outer shell consisted of quartz with only microscopic crystals of biotite. The second had quartz and biotite both about equally developed and evenly intermingled and the center consisted of almost pure biotite in well formed crystals. The minerals occurring in the centers of the bunches also occur scattered throughout the diorite itself in ill-formed crystals. Even magnetite in the body of the rock rarely had regular octahedrons and perfectly triangular faces.

Three minerals are found freely along the borders of these dikes as a result of mineralization, others in traces. The commonest seem to be pyrite and magnetite, less frequently but much more attractive are the amphiboles, tremolite and actinolite. No doubt, too, the large crystals of biotite often found in the diorite have been influenced by the mineralizers. Pyrite is usually scattered through the dikes in single crystals along the border zone. Magnetite is scattered also, but frequently brought together in little aggregates of crystals and rarely in excellent large octahedrons with a brilliant iridescent tarnish. Pyrite is almost always in well formed cubes. Occasionally a large crystal of pyrite contains a smaller one of magnetite. Very often the pyrite is completely altered to a limonite pseudomorph and this before any other weathering begins.

Dikes occasionally contain small inclusions of the country rock, and less commonly dikes divide and flow around larger masses more or less completely. In inclusions hornblende and feldspar grow to larger size and more perfect shapes. Rarely fine small crystals of paragonite and phlogopite occur along the contacts.

The actinolite and less commonly tremolite make very attractive specimens at X-10; whole beds of the former show in the railroad cut along the borders of the dike. At e-19 along the new road around the arm of the big reservoir are quantities of actinolite, but no dike is known nearer than the next square, figure 5. Chlorite in very pretty crystals often accompanies the actinolite both near the dikes and along this road. It may be that these fine displays of these two minerals indicate the presence of a dike and its mineralizing powers, though the dike itself has not been found. If this be true we might be able to trace the dike across the hill from the east end of the dam by the actinolitization of the schist.

Nearly every diorite dike shows some mineralizing effects, either in its own body or borders, or in the country rock usually in all three places. In some cases the chloritization is the only evidence of the dike. In rare instances the dike seems to have done essentially nothing.

The dikes are often slightly metamorphosed. Perhaps half of them show no effects, but the other half show all gradations from the merest beginnings to a rather striking schistose structure. Yet they are not nearly so modified as are the black biotite dikes described above. They must be notably younger than the black dikes. The first evidence of the change is in the flattening of the white mineral spheres. Occasionally this seems to be only that flattening due to flow of the rock. In other places it is certainly a part of the regional metamorphism. All the minerals are banded, the quartz-feldspar bunches are drawn out into light lines an inch or more in length, the micas are all turned with long dimensions parallel to dike walls and the capacity of the diorite to split parallel to walls is marked.

The dike contacts are usually pretty clearly defined. This would always be true in Readsboro on account of the difference in color of dike and country rock if it were not for the mineralization. The best place to study contacts and really see the form of the dike was found at the turn in the auto road above the east end of the big dam and the Whitingham railroad station. Figure 5 shows the intersection of dike and road. Contacts here were essentially vertical and rather clearly marked. The sides of the dike are not parallel in the portion seen and drawn, but that may not mean that the dike is to run out soon toward the southeast, for these dikes are never uniform in width for any considerable distance. They widen out, then pinch up and then widen again.

The Granite Dikes.—While many of the so-called quartz dikes contain feldspar they are not to be confused with the granite dikes, for they are later and are known to cut across the granite. Therefore, they will be discussed separately.

The large granite dike was found on both sides of the river a mile or so above the site of the Davis Bridge. On the west side on the spur opposite the branch from Whitingham, is a small one, only a two-foot body. It was found close to the railroad along its new location. Another dike occurs at c-5-6 west of the reservoir and well up toward the north line of Whitingham township, while a fourth occurs at i-18-19 on the new road from Whitingham village around to the dam just as the new road leaves the old one that led to Davis Bridge. Up over the hill at h-i-9 are found a number of stringers of rather siliceous granite which look very much like the rest and no doubt are the same thing, although the feldspar is in smaller grains and possibly less abundant. All these occurrences are in Readsboro, but they must have come up through the formations below so occur in all formations.

The main dike runs W-N-W by E-S-E and is probably continuous beneath the deep water of the reservoir, for it was traced to the water's edge on both sides. It was followed far up into the hills westward in c-b-a-9-10 where it continually breaks up into stringers, first into two, then into scores, each becoming smaller until they are no longer traceable in the forest and beneath the mantle. Stringers cross beds of Readsboro and run along between them distinctly. East of the river there is a more unified mass from which stringers run out. The central dike with a width of 200 to 500 feet has been traced up from the river through a col between two hills in f-g-h-10-11 to i-12, where it was lost in a tamarack swamp. It has not been found on the east side of the marsh so we were probably near the end. Many branches extend out in varying lengths from this mass, and possibly some or all of the outliers noted as at h-i-9 and i-18-19 may be connected by stringers with this main dike, but we were unable to trace connections on account of drift, woods and other covers.

Mineral composition and texture show a marked similarity in all the localities. Milky to clear quartz makes up from 50 to 90 percent of the rock. It was taken for quartzite in some places until its relations were found. Feldspars occur in every place examined and out toward the central part of larger dikes as much as 50 percent. Crystals vary from very small to one-half inch across in most favorable parts, in good cleavable but not striated, milky to clear well formed shapes. It must have crystallized before the quartz. Magnetite is always present though never notable, it is in tiny splinters and distorted crystals as if not the first to form. Pyrite is rare, but rusty spots suggest a greater frequency in absolutely fresh material. Biotite is usually present though fine grained, and it is well shaped. Sericite is common along all weathered margins as if derived by weathering and probably from the feldspar.

Calcite is the variable mineral. Some samples gave no trace, others effervesced a little and briefly, while at c-14 calcite is present in large, well formed crystals in the midst of the dike, apparently filling seams or veins. This calcite is probably secondary and a product of weathering and leaching downward of calcite. In the central part of the larger dikes and stringers the texture is homogenous, but toward the borders and in the narrower dikes there is obvious banding. The micas are distinctly in layers. The sericite, developed from the feldspar by weathering, also shows banding as if there had been a flow structure in the rock by which the waters, responsible for the transformation had found a way into the rock.

The dikes do not greatly modify the country rock. They nowhere develop the rarer minerals as the quartz-feldspar dikes (see below) have done. But in many places the Readsboro is more siliceous near the contact as if siliceous juices had worked outward, stoping perhaps into the country rock a little and silicifying considerably whatever they entered. Larger and more regular quartz crystals occur along the borders.

The granite weathers less freely than the country rock and makes rather showy light colored exposures visible some distance across valleys because of their lighter color and lack of cover. The areas on the west side of the river by Camp Polly c-10 and those on the east side in g-h-i-11-12 are intervisible. Not only the outcrop, but many loose boulders weathering from the ledges help to make the hillside white.

It may be significant that these granite dikes only occur in the central part of the large anticlinal structure of our area. In doing work east and west of this area thorough search should be made for more of them to test the value of this observation.

The Quartz and Quartz-Feldspar Dikes.—This group of dikes is at once the most numerous, most recent, most widespread on our map, and has been the most active mineralogically. In scores of different localities these forms were noted, 12 to 15 new minerals are developed in and around them, they cut every formation and all other dikes, and are found in squares A to jj east and west, and 4 to 36 north and south. Our observations indicate that they are more frequent in the Readsboro or in the axial region of the largest structure of the region just as are the other dike types.

There are so many places where these dikes can be seen that an enumeration of them seems less valuable than for the earlier kinds of dikes. Most of them are so small that mapping them would greatly exaggerate their size, hence the locations will be given by types and only the more significant places will be mentioned. With the observed frequency of these dikes, and more than 80 percent of the rock covered by mantle, there must be literally hundreds of them. With such frequency they must be connected and intersecting more or less. In fact connections for many feet have been traced and intersections have been noted.

In composition these dikes vary from essentially pure quartz to quartz-feldspar combinations in which the feldspar greatly predominates. One could break sections across some dikes which would be almost pure pink feldspar in crystals one to two inches through.

The dikes vary in size from 10 to 12 feet in H-29-30 down to the thinnest threads. Thickness of one to six inches is very common and can be found almost anywhere Some of these have caused notable mineralization, others essentially none at all. It is probably true that mineralizing fluids were not of the same composition nor abundance in the different dikes, therefore, the results are different. There does not seem to be any relations between the intensity of mineralization and the size of the dike, nor again between the amount of change and the present composition of the dikes.

The large quartz dike mentioned above was traced nearly continuously for about 1,500 feet. The mass found at H-27 is probably a continuation of that at H-30. It has been locally known as the gold vein or the gold mine and there have been citizens willing to invest heavily in the mining of this dike for gold. For their encouragement it may be said that this dike, as well as many others in southern Vermont, has the same general aspect as the rich gold "quartz veins" of California, but like all others seen in southern Vermont it has one notable difference. While many of those in California have gold in them, these do *not* have gold in workable quantities. Some of them have pyrite, more have mica with shiny faces, both of which have been deceivers. In our opinion there is nothing in this vicinity that need to excite the cupidity nor elicit the shekels of anyone. There is very little mineralization aside from pyritization along this large dike. Scores of small ones have accomplished much more than it has.

At S-21 in typical Readsboro a dike of quartz and striated feldspar was found which had carried pyrite cubes from one-fourth to one-eighth inch across. These have oxidized to limonite pseudomorphs, and then mostly have weathered out, leaving the dike studded with rectangular pits. At R-23 and A-26-27 many small quartz dikes occur in the Readsboro. At D-25-27 quartz lenses and dikes occur freely, cutting the rock in all directions. All are thin stringer-like, some white or milky, some iron stained. The stain came from pyrite occurring in and near the quartz. In the country rock, Heartwellville schist, are many tourmaline crystals, some an inch long and as large as a needle, a few one-sixteenth inch in diameter, all are black, occurring singly, in bundles or in rosettes, but in the schist and not in the quartz. Garnets up to one-fourth inch diameter are also common here in the schist.

At the east end of the big dam b-18, quartz dikes cut the Readsboro frequently near the road. Near the dikes but clearly in the country rock are many garnets, which are more abundant along the bedding planes of the schist. No positive proof that the garnets were related to the dikes could be adduced, but it seems probable; and their abundance on the bedding planes then may mean that the mineralizing fluids could penetrate more freely there.

At L-21, in Heartwellville were found quartz lenses three to four inches thick and several feet broad. Along their margins the quartz had penetrated between the sericite folia and pried them apart, freezing and crystallizing there like ice and snow between old leaves. No feldspar or pyrite were detected in the dike or near, but garnets are frequent in the country rock, and in the interbedded folia of sericite. None were noted in the quartz. In one of the quartz dikes or lenses here, were multitudes of tourmaline crystals in radiating clusters. Single crystals two inches long and more than one-eighth inch through pierce the quartz in all directions. Others occur in the schist along the borders. The sericite of the schist seems to be considerably chloritized. No garnets at this place, but occasional felspars were scattered through the quartz. At D-16 is a dike of blue quartz in Heartwellville carrying pyrite and tourmaline.

At q-21, where a black mica dike was noted, quartz-feldspar dikes were also found, but with little mineralization except recrystallization of biotite. The quartz dikes cut across the older biotite dikes.

At u-32 quartz dikes have considerable well developed biotite in their borders as if their presence had assisted the growth of the mica. At w-32 in the green Halifax chlorite schist, quartz dikes seem to be responsible for the growth of actinolite in the country rock. At m-n-12 near the top of the hill, but on its east slope, occur small quartz dikes with much tourmaline in slender black crystals, and with large garnets in the country rock.

Quartz dikes are fairly frequent in the marble. At e-f-34 such a dike crosses the contact of marble and the Whitingham schist, producing much mineralization. The marble becomes coarse crystalline, with micas and actinolite. The dike has black tourmaline and the Whitingham schist has calcite, red and black tourmaline, and pyrite. Much of the tourmaline in the quartz is fine, granular, interbedded with the quartz, alternate layers being one-fourth to one-half inch thick. Gray and pink feldspar is present with the quartz.

The coarsest grained quartz-feldspar dike found in place was at v-21 in typical Readsboro. Pink feldspar crystals were two inches in diameter. No mineralization except recrystallization of some of the bordering mica was found. At R-27 in a pile of boulders gathered from the meadow around, were masses of similar coarse dike. Feldspar was abundant and in crystals one to three inches across. So little country rock was present that mineralization was not noted. This material was not in place where found, but could not have been far from its place of origin, but that place could not be located.

At j-k-18 the quartz dike is in typical Readsboro and has brought pyrite both in the dike and in the country rock.

Quartz dikes are found in the Halifax chlorite schist in a number of places, but they produce less change than in more siliceous rocks. Dikes are known at cc-33 and jj-25 and at y-23. In the latter place the chlorite and quartz-mica schists are closely interbedded. The dike is made up of quartz and feldspar, of which the feldspar is much better crystallized. Large crystals of dark green chlorite have been formed along the borders of the dike, but beyond this recrystallization of the chlorite of the country rock, the dike seems to have caused little change. At dd-20 about a mile south of Jacksonville a dike of quartz and feldspar has been thrust into a dense, dark green, fine grained chlorite schist. The dike is more than 90 percent feldspar and the quartz is simply in stringers among the feldspars as if put in after the feldspar was all crystallized. All along the contacts the chlorite is recrystallized, coarse and harder than the country rock. Probably it is a new mineral. At w-32 a similar dike has developed both hornblende and the coarse dark green mica, from the chlorite schist. The quartz has seeped into the rock until the border line is quite indefinite, in fact a zone of feldspar, hornblende, quartz and mica. This rock is very handsome, but not abundant.

Quoting from the paper by Bray and Emery[1]: "The mineralization which results in some form of mica is by far the most common, and of the micas biotite is the most common form. Muscovite and hydrous green micas also occur. Biotite is present in good crystals along the contacts, extending into dikes and country rock. In the country rock it makes the rock look darker and denser along the contact. In one case some large beautiful crystals were found in the very center of a quartz dike. This phenomenon was probably caused by rapid cooling of the quartz which left cavities where the biotite crystals were formed and later were surrounded by an inflow of more quartz in heated aqueous solution.

"Muscovite is very rare. Phlogopite is as rare as in the diorite dikes, but paragonite is more common and occurs with muscovite in the schists in several places near the contacts. Inclusions of crystals of mica within the feldspar and the reverse are common.

"Epidote is not very common and generally occurs in rather massive form between the country rock and the dike. Large masses of actinolite, beautifully crystallized and associated with quartz are found in such quantities that it must be assumed here as perhaps for the epidote above that the largest part of the basic material for the mineral was already present in the country rock, and that the mineralizers merely changed its combinations, adding silica.

"Ilmenite occurs in medium amounts, almost always within the edges of the quartz dikes themselves, sometimes along the contact, rarely in the country rock. It is not usually in good crystals, but in plates as much as two inches long." A boulder

[1] Bray, Miss H. G. and Emery, A. H., Ohio Jour. Sci., Vol. 23 (1923), pp. 86-87.

found about a half mile north of Readsboro village and just south of quartz dike ledges has a lot of ilmenite in plates located just as quoted. The country rock carries 25 to 30 percent of small garnets and a similar amount of green hydromicas beside quartz, feldspar and biotite. Near the contact in places are fine bunches of slender, black tourmaline crystals, and pyrite was once present as shown by the limonite at present partly in pseudomorphs.

Continuing from the paper: "Magnetite is more common than ilmenite generally, but is usually disseminated through the country rock in imperfect crystals."

When the tunnel was put through the hill from the big dam to the power plant a quartz-feldspar dike was encountered and quite a quantity of the material was brought out and put on the dump. This material has a decided advantage over all other material collected in that it came from far below the surface and showed no effects of weathering. The exact location of the dike could not be learned, but since the hill is synclinal, and all Readsboro schist at the surface it is probable that the tunnel found nothing but Readsboro. This statement holds for the large hill north of the Readsboro-Whitingham road, but will not hold for the southern part of the tunnel. The material referred to came out of the adit at W-23.

The dike consists largely of milky quartz and feldspar, in part striated, in coarse crystals and varying proportions along its course. On the contacts are splendid sheaves of black tourmaline crystals, both in the quartz and the country rock. A coarse crystalline chlorite with a bright green color and very brilliant luster is also common in both. Pyrite and pyrrhotite are of frequent occurrence, possibly the latter the more common. It was carefully tested for nickel and copper with negative results. Garnets of good size, one-half inch diameter and under, are common in the bordering country rock. No ilmenite nor magnetite were detected. Several pieces rich in calcite were found, however. The cleavage blocks were mingled with the quartz, feldspar, and chlorite well within the dike. Some blocks were an inch across and gave no suggestion of having been made after the dike. In places the carbonate looked like siderite and gave a considerable iron reaction, but no magnesium, probably simply a ferrous calcite.

The above discussion of the dikes may be brought to a close with an expression often made during the field studies. This region just missed being an interesting mineral field and possibly a valuable ore area. The later dikes contain some oxides and more sulphides, but aside from the ilmenite and its titanium, nothing in a form to be of much economic value has been found. It seems probable that more mineralization may be found on a lower level only to be exposed after further uplift and another

PLATE XXIII.

From the top of the drift filling seen in Plate XXIV at an altitude of 200 feet above the river, looking north. Steepened slope on left is the youthful steepening in present cycle but done before glacial period. See drift in valley against this steep slope. Late Tertiary peneplain remnants in distance. River flows toward us from center of picture to the right around the drift fill. Rock pile on extreme right is the dump at the adit, fully 300 feet above the river.

erosion cycle or possibly deeper erosion in the present cycle. And with no traces of metallic minerals save sulphides of iron and oxides of iron and titanium and all these only in small quantities, it is no place to search, in the present stage of geologic development, for valuable ores of anything.

STRUCTURE.

Summary of the Data.—Not much need be added here concerning the structure in the area except to bring together all the data mentioned, and correlate them. There is one large north-south anticline, highest in the western part of the area in the broad outcrop of the Heartwellville. This is true even though the oldest rocks do not come to the surface for the Whitingham formation rises here to altitudes of about 2,300 feet, while it is only 1,900 feet where exposed in the Whitingham marble area.

This anticline is known to pitch sharply southward (figure 4.) Evidence is abundant in the southern part of our area, as well as in the northern part of Massachusetts as shown on Emerson's map. The strata dip southward and the lateral outcrops close around the southern end. It is believed to pitch northward also, although this fact is not shown in our area. In 1916 when we were working on the same structure around Wilmington we found strong north dips in the vicinity of West Dover; and the Readsboro-Halifax contact bears northward in Hogback and Higley and then swings around to the northwest. The rocks in Wardsboro and Somerset seem to be similar to those east of the Halifax formation. This point is not yet established. It needs much more work.

This anticline, 10 to 15 miles broad at least, has within its width several short pitching anticlines and synclines, like the one bringing up the marble in the Whitingham area, and those bringing up the older formations near Sherman, at camp, and in Readsboro. The axial fold is only one of these a little larger and higher. Most of the lesser anticlines are short and steeply pitching both north and south. Plate XXIII.

Then over the backs of these mile-to-two-miles wide anticlines are several small wrinkles. In the Whitingham marble area where they show to best advantage, more than a dozen are known in a width of 6,000 feet. The same wrinkled pattern holds over much of the area. It is well known all through the big Heartwellville area in the west, in the Readsboro area of Readsboro village and in Readsboro schist north and northeast of Whitingham village. It is known also in the Halifax schist, and one of the wrinkles in the row of hills east and northeast of Jacksonville running beyond our area, has probably been thrust-faulted along its crest and overturned beside. This schist yields readily to pressure, and develops wrinkles more than some do. Most of these wrinkles are probably less than two miles long, some much less than one, and they will probably not average more than 500 to 600 feet wide. They pitch at both ends and often pass at the ends into the opposite structure, anticlines here, synclines there. No area more than a mile square is known where these folds do not occur.

Beside these three sizes of structure there are two more, though it must be understood that there are no hard and fast lines between the grades or sizes of synclines and anticlines. The next two are smaller. The first may be said to be plications over the backs of the wrinkles. One can find scores of them in almost any area where the rocks are well exposed and reasonably fresh. Boulders over the hills or on the fences show them. There is a group of them on the lecture room table at Oberlin College. Its total length is about two feet, its width less than one. But in it are three folds; at one end an anticline on each side and a syncline in the middle all pitching, at the other end the anticlines both become synclines and the syncline becomes an anticline between them. This specimen came from a stone wall about a mile north of our line in Wilmington township.

The last structure may be called corrugations or crumplings and they occur all over many of these plications. The Readsboro shows them sparingly except in favored localities, but the Heartwellville is rich with them, and the Halifax is sometimes called the crumpled rock, or corrugated slate. These little crumplings are but a fraction of an inch high, *i. e.*, from crest to trough, and a larger fraction across from crest to crest, and they pitch or run out often in less than an inch. There may be finer foldings than these, but the microscope is necessary to see them.

Thus is will be seen that as a whole the dominant structure is the pitching fold, and this type is carried through the whole gamut of size from the large anticline 10 to 15 miles wide and 20 to 30 long to the tiny corrugations in the structure of a small hand specimen.

The problem set us in this area required very careful study of the cleavage, bedding, and jointing in their mutual relations before any reliable work could be done. When the same mass of rock seems to have two dips and two strikes either set of which is equally well developed, and capable of being taken for the true stratification dip one has to look carefully or give it up and search a new place. When new places may be hundreds of feet away, because of copious covering, that particular outcrop becomes critical and must be solved or lose the structure sought. The student finds ample opportunity to tune his wits in an area of this sort. Many of the cases in multiple examples so creditably set out by Dale[1] were found in our area. No need here to describe these structures farther, but the reader who expects to work such rocks is urged to familiarize himself with the thing in the field or with Dale's exposition before trusting his observations of dip and strike.

[1] Dale, T. N., Mon. 23, U. S. G. S., pp. 136-158.

GEOLOGIC HISTORY.

It is the purpose of a geologic history to set forth in chronologic order the events that have produced the results seen. Many of these events have been foreshadowed in the descriptive work already done. Some clew has been given to the order in several cases. It remains here to follow the processes through as they have carried on their work. So far as our area goes the processes involved are sedimentation, regional metamorphism, diastrophism, intrusion and contact metamorphism, erosion, and glaciation. These processes have not always operated alone, nor have they been satisfied with one period for some of them have recurred several times, and their times of operation have overlapped a great deal.

Sedimentary Record.—Since our formations are all conformable and probably all belong to one geologic period and since no observations are possible on older rocks or structures than those in our series, we may well begin with sedimentation. Although one must recognize that sedimentation must take place upon something, and that that something must have some structure, yet we cannot get at these things so must content ourselves with the items available in our area.

The five bedded formations, Sherman, Whitingham, Heartwellville, Readsboro, and Halifax are believed on several counts to be of sedimentary origin.

1. The quartz grains in many places show that they were once rounded and have been more or less completely restored by silica deposition.
2. The suggestion of bedding in so many places and especially the obvious crossbedding seen frequently in the Readsboro.
3. The calcareous beds at the bottom of the series, and the complete conformableness up through the series.
4. The lensy character of the materials in all the formations. Layers lens out in short distances and new ones come in, not like beds of lava nor of volcanic ash, but as if the materials had been washed into their places by active streams or currents. This seems wholly applicable to all but the marble, and with the wealth of mica in many parts of the calcareous rocks it would seem pertinent to apply it to the noncalcareous parts of these.
5. It has been pointed out by Bastin, as cited earlier, that chemical compositions show origins of rocks. The test has been applied to the Hoosac (Readsboro) schist with the result that the analyses show dominance of magnesium over calcium and of potassium over sodium, excess of alumina over the ratio of 1 : 1 necessary to satisfy the lime and alkalies, and a high silica

content. All four relationships point to a sedimentary origin for the formation. Analyses are not available for the Heartwellville and Halifax, but the mineral composition certainly looks as if three of the above tests would apply to each of these two formations.

We must take the position that these five formations are essentially of sedimentary origin. This does not mean that we believe no volcanic dust could possibly be among the materials, but that so far as the record in our area goes it was one essentially of continous water sedimentation. On this well established hypothesis the discussion of conditions will proceed.

There seems little possibility of getting back either to the conditions under which any one of these rocks were made or the compositions of the sediments from which they were derived, except through an interpretative study of the present rocks and the application of chemical, physical and geologic principles to the problems presented. It is obvious that the conditions varied greatly to bring forth such diverse rocks as we now have; that the sedimentary materials varied from time to time, not simply oscillated, but changed progressively from early Ordovician (Sherman) time, to late Ordovician (Halifax) time.

Conditions of Making the Sherman Marble.—This rock material was laid in waters that were alternately reasonably clear and quite muddy, at times even sandy, but on the whole the materials precipitated from solution greatly predominated over the sediments from suspension. Presumably the waters were not close to shore and not very shallow. There must have been enough of currents to bring in and shift about the clays which have been metamorphosed into the micas of today, and strong at times to bring in sands and strew them about. That there was life in the waters seems reasonably certain. Graphite is abundant in places, and in such associations is usually ascribed to the dynamic metamorphism of carbonaceous sediments. Its distribution does not suggest magmatic emanations, nor do the associated minerals. Therefore, its presence here is at least a strong argument for organisms in the waters. The limestone itself is also a bit of evidence that life was present, but it alone does not prove. In the exposures along the railroad at Sherman where the rock has weathered at least 40 years, there are structures standing out in weak relief above the rock surface, which look like the algal forms of unmetamorphosed limestones. These have been so changed that internal structures do not yield to our inquiries, but in general the thing looks in several places like an algal mass a foot or so across. Thus on three counts there is evidence that the waters contained life. Ordovician seas usually did as shown by the records in a multitude of other places. In fact our best evidence that these beds are Ordovician is based on the presence of fossils of Ordovician life in the same beds traced into areas of less metamorphism.

Slowly the calcium carbonate accumulated and at times clays and even sands with the carbonate. Everywhere the marble now contains dolomite. It may have been precipitated by organisms while the rock was being laid down or may have arrived later by dolomitizing fluids.[1] Whatever its source the magnesium arrived before the regional metamorphism that produced the tremolite, actinolite and tourmaline.

The sediments were feebly ferruginous, the iron probably being in the form of hydrates. Every sample of marble tested shows iron, but none has it abundantly. The accumulating sediments probably inclosed boron in traces which has been used subsequently to make the tourmaline. In some placcs the tourmaline is close to or within quartz dikes, but it occurs in many places where there is no sign of intrusion. When associated with intrusion it is never far from the contacts of the igneous bodies, hence here where it is widely disseminated, it may very properly be ascribed simply to the regional metamorphism of the sediments including their recrystallization. Intrusion is responsible for some of it and regional metamorphism for the rest. Tourmaline also has used some of the iron. The sediments probably contained iron enough also to combine with the sulphur of organic origin to make the pyrite.

There was some change in character of the sediments as the deposition went on. The organic matter became more completely oxidized, leaving less carbon for graphite, and the silica and magnesium for tremolite and actinolite became more common. Also the clays became much more abundant as attested by the larger percentage of mica in the marble of the upper strata today.

Conditions During Making of Whitingham Beds.—There is so marked a difference between the marble and the Whitingham schist that a considerable change in conditions seems probable. The change, however, was not to wholly new conditions and not wholly sudden. It consisted in a steady holding of the muddy, most clayey conditions, that occurred occasionally in Sherman seas, without the return of calcareous conditions, so that clays and sands greatly predominated in all layers and calcium carbonate was at a minimum in all. Further, this muddy, silty condition was very constant and uniform, hence the sediments were much alike all through the 40 to 100 feet. The sediments were more ferruginous and more sandy. Life was probably relatively much less significant in the formation of rock.

Inasmuch as the rock is so similar from top to bottom and spread all over the area signifying not only conditions, uniform through the Whitingham time, but also similar over considerable territory, it seems probable that the water was still deep, scores if not a few hundred feet in depth. As noted already, this forma-

[1] Clark, F. W., Data of Geochemistry, U. S. G. S., Bull. 616. This volume is heavily drawn upon in this discussion of the marble and also in that pertaining to each of the succeeding formations.

tion seems to correlate with the upper part of the Bellowspipe limestone of northern Massachusetts. On this fact follows the suggestion that the sources of the clays and sands were not southward, but probably northward. Therefore, shallower seas and the shoreline of Whitingham time lay northward or northwestward from our area.

No fossils were found and little to suggest the character of the life in Whitingham times. It may have been as abundant as in Sherman times, but it was probably not of kinds to secrete calcium carbonate so abundantly. Probably most of the forms enjoying clear waters migrated or perished when the muddy times came, and were succeeeded by those forms less fastidious, such as could live in muddy waters.

Changes Leading to the Heartwellville.—With a thickness of more than 1,000 feet it may be that Heartwellville represents a longer time than either the marble or the Whitingham, but we know such materials as went to make up this rock, sands and clays, accumulate more rapidly than calcareous sediments. Its thinning eastward and southward need not indicate less time, but greater distance from the sources of supply. If true, then the shorelines still lay to the north and northwest, and the hills whose disintegration furnished the waste may have occupied, in part at least, the present Adirondacks area. This does not preclude the possibililty of some waste having arrived from the east, but in our area we have not found any evidence of such sources.

The change in the character of the rock, found as one passes upward into the Heartwellville is not sudden nor marked, which means that geographic changes, and the differences in kind and rate of sedimentation were not great, but in the course of a few feet the transition is complete in the rock from a biotite-quartz schist to a sericite-quartz schist. Therefore, there was such a change in the kind of sediments as might be responsible for the change in the mineral composition mentioned.

Students of metamorphic geology believe very little change in the elements and the relative proportions of the elements occurs during the metamorphism of sediments into schists. The chief differences between biotite and sericite are the presence in biotite of Mg_2 (Fe) with Al_2; and in sericite of no Mg_2 (Fe) but Al_3. It would seem then that the differences in the sediments must be essentially more magnesium and iron in some available form, and a little less of aluminum. Since kaolin, the basis of the clays, has Al and Si in the same ratio as does sericite, normal kaolin might be expected as the foundation for the sericite in the Heartwellville. Since quartz grains would probably be less efficient, less active, in the metamorphic mineral transformations than colloidal silica or hydrate of silica, it may be true that the quartz sand constituent remains about the same in the two rocks, but that in the sediments of the Whitingham there was more hydrate of silica and less of kaolin. Thus on the arrival of the conditions of pressure, temperature and other factors competent of metamorphose, the sediments, those to become Whitingham consisted of quartz grains, magnesium carbonate or hydrate or possibly hydrous silicate, iron hydrates, and some kaolin with free hydrate of silica; while at the same time, those to become Heartwellville contained quartz grains, very little magnesium compounds, only enough iron to be worked into the garnets and tourmaline, and little or no hydrate of silica. These substances may be grouped into two categories, the quartz in one and the rest in another. The two categories varied in proportions from place to place and time to time. There were times for example when almost clear sand was laid and other times when the second group was nearly free from sand admixtures. This variation of ratio may account for the variations in the mineral composition of the schist from highly siliceous to highly micaceous types.

The boron of the tourmaline and the potassium of the micas is believed to have been present in the sediments, for the simple reason that the minerals containing them, tourmaline and sericite, are so uniformly distributed, even in places where dikes occur, that it would be difficult for mineralizers to bring about their present distribution. Moreover, these minerals are just about as frequent far from dikes as near. Analyses of rock tourmalinized by contact metamorphism show no tourmaline or boron more than a few feet from the contact, and show also a sharp diminution in percents of boron and tourmaline as the distance from the contact increases. We are thus inclined to the conclusion that the tourmaline and, of course, the sericite and garnets were developed by regional metamorphism of sediments containing essentially all the ingredients used to make the several minerals.

The only changes in the sediments during Heartwellville time seem to have been oscillations in the ratios of sand and clay ingredients. Calcium carbonate is rare in the formation, graphite has been found but two or three times and all fossil impressions in the initial shales would have been obliterated by the metamorphism, hence we have essentially no record of Heartwellville life. No doubt something lived in the sea at this time, but its record is very meagre.

Readsboro Conditions.—The contact between the Readsboro and the Heartwellville is usually rather sharp, but shows no evidence of erosion. Deposition of sediments was apparently not broken, but the character of the sediments was changed.

Since there is so little calcite in the Readsboro schist it seems probable that lime-secreting organisms were rare and that very little calcium carbonate was precipitated with the sediments. Quartz sand was the most abundant of materials dropped into the seas during this epoch. Clays probably come next, clays consisting largely of kaolin, but since the dominant mica is biotite in the schist there probably were hydrates of iron and silica and possibly hydrous magnesium silicate as talc or serpentine. It is hardly probable that the magnesium came down as carbonate, for carbonate even now is very scarce in the Readsboro.

In the Readsboro tourmaline is very rare except along dikes, hence it may be inferred that the sediments were essentially free from boron, but the micas pretty generally contain potassium, hence it is inferred that potassium was widely distributed, but never abundant in the sediments. It may have been entrapped as potassium aluminate or silicate, and in the metamorphism, kaolin and one or both of these compounds may have been linked up together with dehydration and recrystallization forming mica.

Because the proportions of quartz and micas vary so much up through the formation, it is a reasonable supposition that the ratio of sand to clay in the deposition varied. This variation is more frequent and more marked than that in the Heartwellville. It is such a variation as should be associated with shifting currents, often vigorous ones. In fact it looks as if such succession of sediments could best be interpreted as of delta origin, hence relatively near shore and in shallow waters. Frequent cross-bedding in the Readsboro supports this interpretation. Cross-bedding is still more frequent and often very striking in the same formation in Wilmington township to the north. On the assumption that the shoreline and the sources of sediments are still lying off to the northwest it might be safe to infer that the sedimentation had gone on so far since change of level that the shoreline was building out into the sea and hence new lands were encroaching upon the waters just as any deltas, Po or Mississippi for example, are doing today. And following this interpretation, the explanation of the Rowe and Chester formations comes naturally. Emerson in his geology of Massachusetts expresses his conviction that the Rowe is thinning northward considerably and the Chester to some extent. Our work, as already shown, gives these two formations much less of thickness than is ascribed to them in Massachusetts and we find them so like the Readsboro that we do not map them separately. Thus what seems probable is that during the time of making, the Hoosac and such part of the Readsboro as is equivalent, the level of the sea rose less than the aggrading, so that at the end of that time the sea was about full out from the shoreline southeastward to the Massachusetts-Vermont line. Then very little deposition occurred in our area, just enough to level up to sea-level, while larger quantities of sand and clay were carried beyond and laid in northern Massachusetts. This would make the deposits thick in Massachusetts for Rowe and Chester times and very thin in our area. They would be different too from those below. There probably then followed the oscillation of conditions resulting in the interbedding of Readsboro and Halifax. Such oscillations could be brought about by intermittent depression of the sea floor alternating with active aggradation. The sand-free (or nearly free) muds of Halifax-like rocks were laid then when waters were deeper, and the beds with more sand when the aggrading had shoaled the waters. Then the next Halifax-like beds would follow another small submergence and finally, by more submergence, proper depth and other conditions obtained to make the beds for the Halifax formation.

We find evidence of an unconformity just beyond where we have mapped, cutting, in the present topography N-N-E—S-S-W from a point a mile east of West Halifax village to a point three to four miles south of the village. This is also reported in Massachusetts by Emerson. Nothing more need be said of it here, for it was beyond our area, except to suggest that it means an uplift which closed the series of Ordovician rocks with which we have been dealing, probably long before Ordovician time really closed.

Returning to the Readsboro sedimentation briefly, something should be said of the bedding and of the feldspar content. In the lower part the bedding is often quite even and the rock splits into excellent slabs. These even-bedded layers are not local, but can be traced several miles. In fact it seems probable that fine, split-rock occurring north of Wilmington is in the same horizon as that found around Readsboro and northward. Such even bedding over distances of 10 to 12 miles seems to mean very early stages of delta building when the waters were deeper, so that similar conditions prevailed widely, when waves and sea currents laid the sands and not river distributaries. We have wondered how much cross-bedding and the cut-and-fill process have had to do with the confusion of bedding and foliation. It would seem that in such a place as this was, foliation or schistosity might be more persistent in direction than delta-bedding, and if developed with the bedding in one place would have to be at an angle with it near by, unless its direction changed as frequently, and in the same way as the direction of the bedding. We could do nothing with this problem this past summer, but have left it in the hope that some future time may avail to work it out.

In regard to the feldspar in this formation, two interpretations are possible from a purely empirical viewpoint. First, that the feldspar was eroded from the lands and laid in small grains with the sand and hence is primary with reference to the sediments, *i. e.*, that it has always been feldspar ever since it was laid down. Second, that kaolin and other ingredients of the sediments have been combined to make the feldspar, hence that it was made by metamorphism after the sediments were laid.

The first interpretation seems difficult to apply here. If the rocks being destroyed to make the sediments of our formations were so far disintegrated as to make clays and hydrates, it seems hardly possible that so much feldspar could have escaped during all the weathering and transportation. The more improbable does this seem when one recalls that feldspars are quite unstable in the air, for they are attacked by water alone, by water containing carbonic acid gas, and by acid as well as by alkaline waters.[1]

By the second interpretation the only difficult part of the problem is to find enough potassium and sodium to make the feldspars. It seems probable that a plenty of these elements could be caught by the sediments as they fell through the waters and carried down with them, providing the waters were marine. We have no reason to question the supposition that these sediments were laid in salt waters in an arm of the sea with possibly open connections at both the north and south ends of a broad strait or trough, hence essentially salt water throughout. This general geographic distribution of land and water seems to be well confirmed by abundant findings in New England and bordering lands.

Our interpretation then for the presence of the feldspars in the Readsboro is that sufficient kaolin was laid with the sands in these delta beds to form the basis for them as well as for the micas, and that from the marine waters sufficient sodium and potassium salts were also incorporated, that when the metamorphism came the clays were dehydrated and the sodium and potassium combined with the aluminum silicate and built up the feldspars with the other new minerals. There is nothing in such an interpretation to do violence to our knowledge of the generation of feldspars. It is but a step further than the making of muscovite and sericite. This step has been taken artificially by C. and G. Friedel[2] when they succeeded in preparing orthoclase by heating together potassium silicate, muscovite and water at a temperature of 500° C. By use of a longer time than is possible in a laboratory experiment, and the pressure of thick superincumbent rocks, this process might be successful at a somewhat lower temperature.

The Conditions Obtaining During the Making of the Halifax Chlorite Schist.—The schist is made up of a large percent (75 to 90) of chlorite and a small percent of quartz (5 to 20) with various accessories as hornblende, actinolite, garnets, sericite and other micas and, rarely, feldspars. The deposits from which this group of minerals could best be made would have first a small percent of sand and a large percent of kaolin. These two products of the decay of crystalline rocks would be rather constant. In addition for any of the commoner chlorites,[3] magnesium and iron must be present. These no doubt would be in the form of hydrous

[1] Clark, F. W., Data of Geochemistry, U. S. G. S., Bull. 616, p. 367.
[2] Friedel, C. and G., Compt. Rend., Vol. 110, 1890, p. 1170.
[3] We do not know what chlorites are present, but we believe prochlorite and clinochlore greatly predominate.

silicates or hydrates and more than likely largely colloidal. Inasmuch as, in the hydromicas, the ratio of alumina and silica is not 1 : 1 as in kaolin, there should be an excess of the one lacking in each case either as a hydrate or a soluble oxide, and preferably for ready reaction, in colloidal form. For example, if a mica with a ratio of alumina to silica of 2 : 3 is to be made there must be in addition to the kaolin a considerable amount of other available silica to enter into the new mineral; on the other hand, if the new mica is to have a ratio of 14 : 13 or 8 : 6 there must be present sufficient available alumina to make up the deficiency in kaolin. Probably in the clays of this formation there were present, generally, excesses of silica. The actual reactions are not as simple as this statement would seem, for probably most of the micas are mixtures (isomorphous or not) of several more elementary compounds in varying proportions.

The hornblende is usually in small quantities and is actually usually limited to a few thin horizons. It contains more calcium and less magnesium than the chlorites, hence the beds from which it is derived might well vary in composition so as to have calcite or calcium compounds competent to enter the reactions producing hornblende. Experiment[1] has produced hornblende in three months by heating under moderate pressures, and with temperatures of about 550° C., hydrate of silica, alumina and the hydrates of magnesium, calcium, ferrous and ferric iron. These substances are all possible in clays, with kaolin as a basis besides.

Garnets are easily formed in shales with ferrous iron. The pressure under the strata laid later is sufficient and the temperature need not be high when acting through long periods of time.

Thus it seems, for all the present schists in the area, varying sediments are competent under regional metamorphic conditions to produce the rocks found today. Probably in every case the sediments are the products of thorough hydration, oxidation, and comminution, hence long weathering, transportation and sorting with final precipitation are necessary to produce them.

The sedimentary record described in the last few pages did not stop with the making of the rocks described. These rocks now at the surface are profoundly metamorphosed. Pressure, and temperatures of several hundred degrees have been necessary to effect the changes. Sufficient pressure and heat could not be applied at the surface, hence we assert that hundreds, possibly a few thousands of feet of sediments more were laid than are preserved to the present day. Further evidence of these other sediments is found in the igneous material now at the surface. It could not be in its present form nor could it have accomplished the contact metamorphism seen with it, without temperature and pressure even more than is required for the regional metamorphism, hence again the thick cover of later sediments. Just when

[1] Chrustschoff, K., Compt. Rend., Vol. 112, p. 677.

the sedimentary record closed may not really be known. Silurian and later rocks are known very near east and south and they were probably laid over our area also.

Metamorphism, Folding and Intrusion.—Following the sedimentation came the pressure, heat and mashing, the folding, crumpling, plicating, and wrinkling, the shearing, jointing and probably faulting. There were four periods also of igneous intrusion. Most of these things have already been discussed in other connections. They must have proceeded periodically during much of the rest of Paleozoic time, culminating in Pennsylvanian or Permian time in the closing up of the Appalachian revolution. Some of the igneous activity, however, may have come considerably later. Their results are the metamorphism already thoroughly set before the reader, and the folding also minutely described. The metamorphic rocks and geologic structure resulting are already familiar.

Metamorphism and folding were not separate, but more or less synchronous. Much of the former has structures definitely related to the folds of the latter process. If the folding brought the rocks above sea-level, which seems almost inevitable, then there was erosion also during later Paleozoic time.

The folding and other processes mentioned in the previous paragraph affected so much, not only of our area, but of that on all sides of us, and affected all of it so similarly that it is called regional metamorphism. Some of the general, regional metamorphism had been accomplished before the intrusions began as is shown by the fact that the oldest intruded material is less altered than the country rock. The black biotite intruded material has wherever seen been modified some. It is schistose in every locality seen, but it certainly has suffered less than the rock surrounding it. Moreover it is in the country rock usually along the plains of schistosity rather than along bedding planes.

These facts do not date the folding nor the metamorphism nor the igneous intrusions, but they do correlate them. There is no doubt that the folding and metamorphism were synchronous, and probably as little question that both occurred in Paleozoic time. Consequently the earliest intrusions were Paleozoic. Inasmuch as the earliest intrusions were involved in some of the metamorphism they must have come before that process ceased, hence in Paleozoic time too. Again the second intrusion, that of the dark, diorite dikes also occurred before the metamorphism ceased, for many of these dikes show some schistosity and other evidences of the metamorphic processes. For two reasons we believe the diorite was intruded long after the biotite dikes. First, it cuts across the biotite dikes. Second, if the relative degree of modification may be taken as a guide the second dikes were put in place a long time after the first, for many of them show absolutely no effects of the metamorphic agencies. But since some of them do show some effects it is reasonable to date the diorite dikes near the close of the metamorphism or probably late Paleozoic.

The granite dikes show no effects of the mashing, folding, crushing and schistosity so obvious in the older rocks, hence we infer that they came into their places considerably later, too late in fact to be involved in the regional metamorphism. They are responsible for a little mineralization along their contacts, change which is superimposed upon the regional changes. Thus the order of events becomes thoroughly established. And with this order we must assign the granite intrusion to post-Paleozoic time providing our dates for the regional metamorphism closed with the Paleozoic. We would be willing to date the granite later than the Triassic, leaving the Triassic for the basic intrusions of the Connecticut valley alone. It might be unreasonable to place basic and acid intrusions in the same time and so close together. We have no evidence that they are, or are not, related. The granites may have preceded the Triassic trap so far as our studies are concerned.

There must have been much erosion in the region by the time the granites were intruded, but this erosion had not reduced the land nearly to the present surface, for even the intrusion of the quartz and quartz-feldspar dikes came at least to the present surface and they crystallized there too, in excellent form, hence must have been sufficiently covered to have cooled slowly under pressure. And we may be sure too that these dikes came after the granite intrusions, because they cut across the granite as across the country rock.

Not only are these quartz-feldspar dikes coarse crystalline, everywhere, even coarser than the granite and much coarser than the diorite, but also they have produced a lot of mineralization or contact metamorphism. This work could not have been accomplished without heat, hence cover and pressure. The actual mineralization has been fully described on previous pages. Its date is all that needs discussion here. With reasonable certainty then we may say these dikes were here before the later cycles of erosion, which wore the land down to the present surfaces, but they came well after the granite intrusions, hence still longer after the regional metamorphism ceased. While actual dates cannot be established for the quartz-feldspar dikes it would seem reasonable to consider them as belonging to late Mesozoic time. It is entirely possible that connections outside our area may be, or have been, established that will locate them chronologically, both differently and more securely than we can. We know of no evidence that will do more than we have done above and we realize that these actual datings are little more than conjectures. We are open to suggestion, evidence, and conviction from external sources. All we are sure of here is the chronologic order of the events.

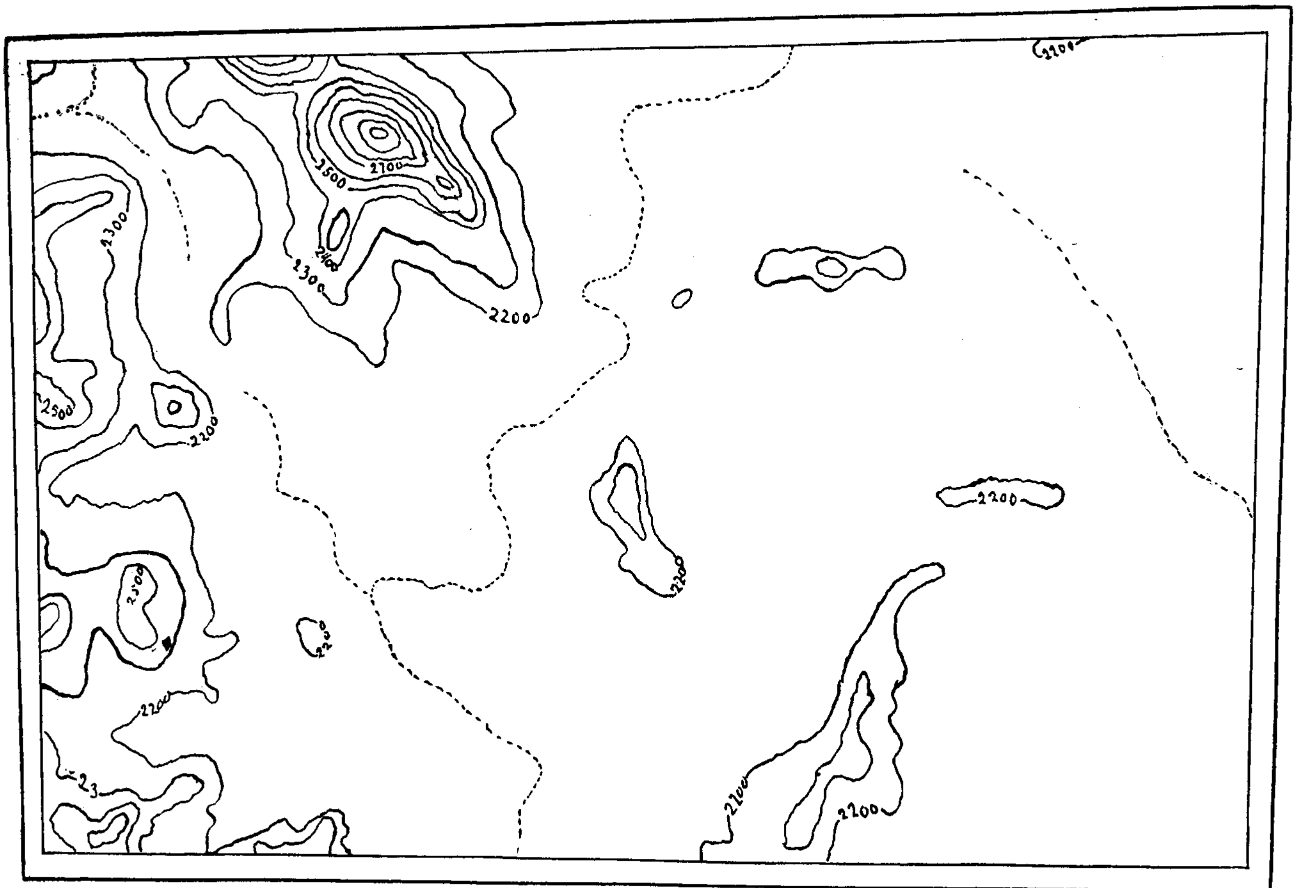


FIGURE 6. Contour map to represent roughly what the country would have been like at end of first recorded erosion cycle, if elevated to present level but without any dissection. Broad, nearly level areas with a few monadnocks rising 200 to 800 feet above the valley floors. The map may also be thought of as showing the topography if the present forms should be filled in to where they were when the second cycle began.

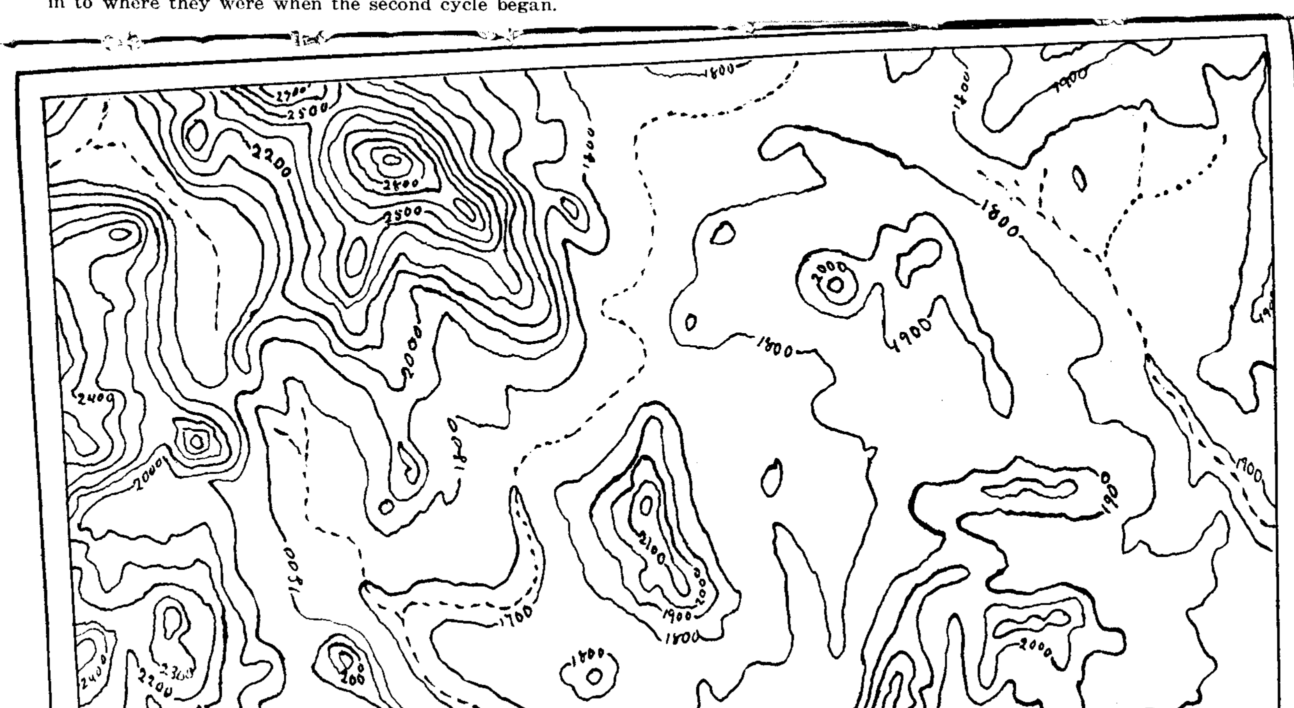


FIGURE 7. Contour map to represent roughly what the country would have looked like at end of second recorded erosion cycle if elevated to present levels. Broad mature valleys have been carved in the valley plains of Fig. 15. Some monadnocks still show but they are 400 to 500 feet higher above this second plain than they were above the first. Present streams have already carved trenches in floors of valleys of this second stage. This map may be thought of as representing the appearance of the present country if it should be filled in as it was at the end of the second described peneplanation.

Our area seems pretty positive on this matter so far as we have outlined it above.

Erosion and Erosion Cycles.—In the Outline of Topographic History, a section in the Introduction, mention was made of extensive erosion, and even of several erosion cycles, and of glaciation followed by post-glacial erosion. In that section, however, the evidence for these things was not discussed nor even presented.

That there has been profound erosion in the region is established by two independent lines of evidence, one of which has been suggested in discussing metamorphism. First, the rocks now at the surface or just below the mantle rock are everywhere crystalline. They are nowhere such rocks as can be made at the surface. Where igneous they are crystallized, not glassy or stony; dense and solid, not scoriaceous and vesicular; coherent not loose, ash-like. Thus their character indicates that they were not made at or near the surface where now found, but under deep cover where pressure kept them dense, preventing the gases from expanding and giving them a porous texture. Their crystalline character stands for heat through a long period of time, long enough and hot enough for the several generations of crystals to form, hundreds of years at least of very slow cooling from temperatures sufficient to make the rock flow. Cover again is necessary to keep this heat in for the centuries of slow crystallization. Just how many hundreds of feet of cover are necessary cannot be said, but it is certainly quite apparent that no valleys could then have been carved down nearly to what is now the surface rock. There must have been thick cover, hundreds, possibly thousands of feet of rock continuous over the country above what is now the surface. This does not mean necessarily that the land was then thousands of feet higher above sea-level. The rocks constituting the present surface may have been below sea-level, even hundreds of feet when the intrusions were made. Now if these intrusions were made into country rock and crystallized there when the rock was deeply covered, and if the intrusions are now at the surface, deep erosion must have occurred to remove the cover.

Further, the country rocks to the top of the highest hills and mountains in the area, and even in the Haystack and Greylock ranges respectively on our north and south, are metamorphics. These higher summits in our area are about 3,000 feet and in Greylock and the Haystack range over 500 feet higher. The metamorphism shows no signs of being less at the summits than elsewhere. All these metamorphics are such as can be made only under great cover and pressure, and the cover was essentially as effective over what is now the tops of mountains as over what is now valley bottoms, 2,000 to 3,000 feet lower down. Hence the cover must have been so thick that an additional 2,000 feet made

little difference. One surely is safe in assuming a thickness of at least a mile covering these mountain tops, possibly more.

Another item in the rocks that testifies to the presence of former thick cover is the folding. The intensity of crumpling, plicating, wrinkling and grand folding has been fully described. Such folding and plication could not be carried on without heavy cover else the rocks would break and not bend. Further, the large folds if restored would carry the layers very much higher up. We have seen the large anticlinal structure running north and south across our area with the oldest rocks cropping out in the axis west of Readsboro and Readsboro Falls at altitudes of 2,400 feet. The Readsboro formation with a thickness of 4,000 to 6,000 feet outcrops on both flanks and around the south end as if it once had gone entirely over the anticline. Possibly the Halifax went over too though the evidence is not as clear, and if it did go over probably not with the same thickness now holding in the Halifax region. This matter of structure has been set out fully enough to make it clear that at least 5,000 feet of material has been eroded from our high parts in the west, and similarly large thicknesses in the central part. The same folded, plicated structure continues to the east and probably a similar amount of cover once lay over it. Hence extensive erosion is established for the whole area, on the grounds of rock texture and structure.

The second line of evidence is in the erosion forms themselves. It was stated in the Outline of Topographic History and described farther under Topography that the most mature topography is well up in the hills. If one climb to altitudes of 2,300 to 2,400 feet in the western part of the area where he can look out east and south, he will be impressed with the number of places and amount of area about at his level. He will see little evidence of the great valleys carved hundreds of feet below that general level, in which active streams run, and busy roads and towns nestle. Land from 2,000 feet up to his level or a little above, will seem to dominate the country and he will see a few broad rounded summits rising above this level. Such a general level, while not nearly a level surface or a plain, is called a peneplain or "almost a plain" and is known to represent an ultimate stage in subaerial denudation. Streams starting above this level have carved valleys, gorges first, down to this level; then they have widened out the valleys, and through the centuries, by lateral planation and headward erosion they have succeeded in wearing away nearly every thing above this level The only remnants left above the peneplain are the well rounded hills such as the 3,024 foot hill about four miles north of Readsboro, and the rest of its range on north to Searsburg. These rose as hills 500 to 700 feet above the general level and there probably was no land lower than about the present 2,000 foot surfaces. Thus there was a total relief of probably not more than 1,000 feet, possibly not more than 700 to 800 and the steepest slopes were farthest back from the streams in these residual hills. Such hills are called today monadnocks after a very typical residual hill in New Hampshire called Mt. Monadnock.

Thus we have in these upper hills abundant evidence of long continued erosion, and deep enough to plane off all that was above this level. It is obvious that the streams could not develop a peneplain like this at an altitude of 2,300 feet above sea-level where it now is. It was probably developed at an altitude of not more than 200 to 400 feet if as close to the sea as it is today. This means, of course, that the highest hills of the area were probably not more than 1,000 feet high at that time. When that time was, is less easy to establish, but it is believed to have been in the early Tertiary. The peneplain then probably was finished after the last intrusions. It may have been begun earlier than the intrusions. There may have been, probably were, several cycles of erosion as complete as this, before this one began—cycles whose records were completely destroyed by the erosion of this cycle.

So the forms due to erosion, still preserved in the hills, as well as the textures and structures in the rocks help to demonstrate the profound erosion to which this region has been subjected.

The Second Peneplain Level.—If one climb the western hills only to the 1,800 or 1,900 foot level he will see even greater areas at this level or near it than he saw at the 2,300 foot level. More land will be above his level, and the areas distinctly below him or lower than 1,600 feet will be practically all out of sight. They are usually in such narrow valleys that their presence is scarcely realized when one is 200 to 300 feet above and back a short distance from them. The view presented suggests another peneplain, less complete (*i. e.,* less level and with larger and higher areas above it) than were seen in the higher view. If the observer be in the region around Whitingham or Jacksonville, however, this level looks even more like a peneplain than the higher one did in Readsboro township, for there are fewer, and only lower monadnocks here. Very few summits rise over 2,000 feet and these are broader and more advanced-mature than those above the higher peneplain, in Readsboro.

The interpretation is simple. The first described surface elevated to where its remnants are today may be represented roughly in figure 15. After the making of this peneplain described as averaging about 2,300 feet high, another uplift occurred. This uplift may be roughly measured by the vertical distance between the upper and lower peneplains, a distance which seems to be about 500 feet.

Such an uplift, of course, rejuvenated the streams and they began to deepen their valleys to the new level. As the centuries

went by they cut, first, gorges, down to the new base level, then wider valleys until the whole succession of steps of peneplanation were carried out as in the previous cycle. The process did not go quite as far as in the previous one, as is shown by the fact that quite a lot of the previous erosion surface is still preserved, but it went far enough to bring in advanced mature to old slopes over most of the area above what is now the 1,600 foot level in the eastern part and the 1,700 to 1,800 foot level in the western part. The general appearance of the surface at this time, with all remnants elevated to their present levels may be shown by figure 16. Its development seems to have been pushed far enough in the east, as was that of its predecessor, to essentially wipe out all larger monadnocks, but in the west like the earlier cycle it did not reduce all the monadnocks. This suggests that the Heartwellville and lower Readsboro may be a little more resistant than the upper Readsboro and the Halifax.

This cycle probably closed in later Tertiary time somewhere, as shown by what has occurred since. There was time, after it closed, for advanced youthful dissection of the peneplain before the glacial period, for the new valleys to be developed with reference to a new base level to depths 400 to 500 feet below the last. But there was not time for these valleys to be widened out into really mature forms, nor was there time for the streams to become graded to the new base level. Therefore, we shall assume that the second cycle discussed above closed in late Tertiary time, but not immediately prior to the glacial period.

With the closing of this cycle came the uplift which put the streams again at a new task, and the third cycle was started. As suggested in the above paragraph this third cycle did not go far until interrupted by the coming of the glaciers.

The wave of rejuvenation due to the last uplift is working up the rivers. Its effects and the limits of the uplift are much clearer in Massachusetts just south of our area than they are in our area. (See Hawley quadrangle.) The Deerfield is much more obviously entrenched in Monroe, Florida, Rowe, Charlemont, and Hawley townships than in our area. In these units the main stream is in a trench with a definite shoulder around the 1,800 foot line in the north, and the 1,600 foot line in the south, and its tributaries show the effects of the rejuvenation, reaching two miles up stream in Monroe township; four miles in Florida as on Cold River and its several feeder brooks; and five or six miles in Hawley and Buckland townships as shown on Chickley River and Clesson Brook and their small tributaries. The undissected upland remnants of the second peneplain are obvious everywhere above these more recent gorges.

This third cycle then had only gone far enough to work out these valleys in advanced youth before the glacial period was ushered in. The Deerfield had done the most to enlarge and deepen its valley, but its channel had not become graded by a large item. Down in Greenfield and vicinity the valley floors are 120 to 140 feet above sea-level and this is 100 miles from the sea. In the southern part of our area the stream bed is 1,020 feet above sea-level and only 20 miles in a bee line from Greenfield. This gives 900 feet fall in 20 miles, while the Connecticut has 120 feet in 100 miles. The Deerfield grade is over 37 times as steep. The stream-level of the Deerfield at the north side of our area is 1,430 feet. This gives 310 feet fall in 7 miles across our strip, a grade almost exactly the same as that for 20 miles below us or about 45 feet per mile. The Connecticut has a steep grade in this lower 100 miles compared with that of the Mississippi in its last 600 miles. It is thus easy to see that when the Deerfield shall have reached even such a grade as the Connecticut enjoys it will be much nearer sea-level in our area than at present. In fact, when it has a grade that shall be coordinated with the present grade of the Connecticut its channel floor will not be more than 200 feet above sea-level at Readsboro or 900 feet lower than at present. The Connecticut already has about such a grade as this, way above Brattleboro, or as far above Greenfield as is our area.

These figures have been given to show that the Deerfield is not nearly down to base-level in our area, that it has 900 feet at Readsboro and 1,200 feet at our northern boundary to cut before it reaches grade with reference to present sea-level. It probably will cut down most of this distance before it broadens its valley greatly, *i. e.,* before it goes far toward developing a peneplain in the present cycle. These figures too give some suggestion of the amount of uplift which has occurred since the close of the last cycle. Presumably the last peneplain, now at the 1,700 to 1,800 foot level, was made within 200 to 400 feet of sea-level. It has then been elevated about 1,400 feet in our area, whereas the first peneplain described was only raised about 500 before the second developed. Obviously the area is destined to become much rougher before it becomes smoother or leveler—much rougher indeed than it became in the previous cycle, because it is so much farther above sea-level. Summing these altitudes up in a tabular form they may be stated as follows:

3,000 feet	=	Summit levels of today.
700-800 feet	=	Relief at close of first cycle described, = height of monadnocks of the times above stream levels.
2,200-2,400 feet	=	Altitude today of oldest peneplain preserved; may be of early Tertiary age. Made 200-400 feet above sea-level.
500 feet	=	Amount of uplift of the oldest peneplain; second cycle began on this new lower base-level.
1,700-1,900 feet	=	Present altitude of second peneplain, made near sea-level, and elevated in late Tertiary time.
1,400 feet	=	Amount of uplift since completion of second peneplain—represents depth to which present streams may carve their valleys.
200-400 feet	=	Level down to which streams may cut in present cycle.
0 feet	=	Present sea-level.

This statement thus far does not deny the possible subdivision of either the 500 foot or the 1,400 foot uplift, into several uplifts, and consequently the times that their corresponding cycles represent, into several cycles. This probably will be quite possible nearer the coast. If there were more uplifts and cycles than we have found they should be found somewhat nearer the coast. We have been unable to identify more than two in our area in the time at our disposal.

Nor does this statement preclude the possibility of earlier cycles. We are sure there were earlier cycles—cycles whose records in forms are gone, but whose certainty is established by the great erosion that took place above our summit levels. A plane tangent to the higher monadnock summits from Haystack and Pisgah northwest of Wilmington, spreading to the south, southeast, and southwest, would descend seaward south and east, possibly it would descend westward. Such a plane might represent approximately an ancient peneplain whose making absolutely destroyed all previous erosion records. Even these summits must have been lowered by erosion, many feet in the cycles that have rolled by, so that at best they only approximately represent an erosion surface.

Returning to a further discussion of the third cycle initiated by the 1,400 foot uplift some time before the close of Tertiary time, it may be pointed out that its date is approximated by noting how much has been done, in the present cycle. Most of what has been accomplished was done before the glacial period. This is asserted on the ground that there is glacial drift in all the valleys of this cycle. Plate XXIII. In some places drift of two ages was found in them. It probably occurs in most places in the valleys unless removed by stream erosion after its deposition. Further, the form of the rock valleys has probably been but little modified by streams since the ice came on. Could we get out all the drift from the valleys we probably would have forms much as the streams had made them between the uplift and the first ice invasion. Hence we can speak of these valleys thus emptied as the work accomplished in a short, immediately preglacial cycle interrupted by the ice age.

In the rock forms then we have, with the exception of two items, essentially what the ice found when it came. First, all was mantled with residual rock waste. This mantle no doubt was deep except where the recently rejuvenated streams had carried it away. Second, the ice itself was the means of abrading and plucking, polishing and smoothening of many rock surfaces, thus modifying to a small degree the rock forms found. There were then when the ice came, the monadnocks of old rounded form rising above remnants of an old peneplain whose altitude was roughly 2,200 to 2,400 feet above sea-level. Plate XXV. There were below this fragmentary peneplain gentle slopes and larger remnants of a second peneplain much of which was 1,700 to 1,900 feet above sea-level. Then there were, below this level, principally along master streams, steep valley walls and youthful valleys down generally below present stream-levels. In these valleys were torrential streams as at present (figure 17), only then usually on the rocks. Their grades no doubt were nearly as steep as those of the present streams. They probably had no falls but may have had some rapids. They were rapidly deepening their valleys. No lakes adorned the scenery. It was probably wholly forested.

Glaciation and Its Effects.—In this chronological statement the coming of the continental glacier was the next event. This paper is no place for any discussion of causes or reasons for a glacial period because our area no more than any other holds the key to causes. But we do have abundant evidence in the area that the ice came, and came largely from the north, spreading deeply all over the area and far beyond. It overrode our highest hills with apparently about as much power as it had in the low places, possibly it had more, because less restricted. It had weight enough to hold its tools and carve the hilltops just as severely as any other part, therefore, we infer that the ice was so thick that a matter of 2,000 feet, or the measure of the rock relief, was an item of small moment in its thickness. If it were 4,000 to 5,000 feet thick over the hills, 6,000 to 7,000 feet in the valleys would not do much more work.

Old drift was identified in several places in the area, beneath new fresh drift, establishing the fact of at least two advances of the ice. Phenomena farther south, in and near New England, confirm our findings on this point much better than they could possibly be proven by our drift features.

A stream diversion in the northwest part of our area helps to date the ice advance. A study of the topography up the West Branch of Deerfield shows a sharp narrowing of the valley two miles and one mile below Heartwellville to a width much less than it is up the branch anywhere for four or five miles, or even up the small brook northeast of Heartwellville toward Searsburg. This last is all in the same kind of rock and cannot be explained on the rock-resistance basis. North Branch Hoosic River rises about a mile southwest of Heartwellville against a large drift

obstruction in the valley, and a tiny tributary of West Branch Deerfield also heads against this drift and flows north. The valley where this plug occurs is broad and mature as anywhere immediately above or below or for miles up West Branch Deerfield.

The probable interpretation here is that before the ice came, a stream heading up in the Camp and Beaver Meadows, and several other notches in the divide, flowed southeast to the present site of Heartwellville then southwest to North Adams; that two small streams from north, and southeast converged on Heartwellville, that during some stage in the ice advance or retreat, ice so lay as to obstruct this course between Heartwellville and Stamford, delivering considerable water eastward at Heartwellville. This water was forced to escape towards Readsboro and being laden with waste was able to saw down the col over which it had to flow and thus open up a good route from Heartwellville southeast. Whether the real col was just south or north of the present Readsboro Falls is immaterial to the interpretation. It seems more probable that the narrower notch south of the falls were the col.

So effective were these overflow waters that when the ice dam withdrew, the smaller obstruction consisting of drift southwest of Heartwellville was able to keep the stream to its glacial course and the diversion was complete.

A study of the notch near the falls makes it clear that the transgression was not first effected in Wisconsin glaciation. The slopes are too mature, the valley too wide and Wisconsin drift too abundant in the notch. If not Wisconsin then of course it must have been earlier. In comparison with other such notches whose dates have been worked out on independent local evidence, it seems certain that this notch has been maturing as long as all post-Illinoian time and possibly much longer; hence the diversion may well be ascribed to the advance of Illinoian ice or even be taken as evidence of earlier glaciation. The conclusion follows as a corollary that the ice spread into this region at the time of the diversion, from the west and northwest and not from the east.

The drift plug southwest of Heartwellville is out of our area and was not studied in detail. It is morainic in form, and hence was made at least in part during the withdrawal of the last ice, but there may be much more to say about it. There may be, for example, an Illinoian core in it overridden by Illinoian ice then by Wisconsin ice and later mantled by Wisconsin moraine forms. In any case it is a drift plug and the stream has been diverted probably by an ice plug in about the same location. Deerfield River is the gainer of seven or eight miles of stream, and 20 to 25 square miles of land.

A lesser diversion has been suggested in the northeast corner of Whitingham township. At Two-way Pond two miles northwest of Jacksonville the drift is thick, the old rock valley is advanced mature and there seems no reason in the rock forms for a divide here. The pond at Jacksonville and the stream through it, seem to be out of topographic adjustment, for the lake lies in a narrow rock valley scoured severely on both sides, while just upstream above the lake the valley widens out much more maturely. The rock is of the same formation essentially along the strike and would seem to present no reason for such discordance. Rock is not known northeast of Two-way Pond for a mile or more. The drift is thick covering all. A tributary from the north coming into Whitingham township almost exactly in the middle of its north line, at present turns west and flows down into the big reservoir, making a distinctly barbed turn.

With all these facts in mind it is suggested that this barbed tributary formerly flowed southeast toward and beyond Two-way Pond, and that the narrow valley it now occupies from the turn down to the reservoir, is a combination of a transgressed col and a short stub valley. It is further suggested that the drainage from one to three miles north of Jacksonville and a little farther east than the Whitingham town line, flowed westward and southwestward into the mature valley just southeast of Two-way Pond and then on southeast as East Branch North River. This branch seems to show rejuvenation from the Connecticut River up as far as Jacksonville. In this plan for the old drainage probably no tributary came down through what is now the Jacksonville Pond. That notch was no doubt cut through in glacial time partly by diverted drainage and partly by the ice scour.

Another case of drainage modification is around Sadawga Pond, but thus far we have no suggestion to make as to what has happened. We are sure that the drainage of the region did not go out southwest toward Sherman, although the hill topography strongly suggests that outlet. Rock is known all across the col between the 1,600 and 1,700 foot lines and almost all the way above the 1,700 foot line, while the pond itself is not up to 1,680 and, of course, the valley floor, some distance lower.

There have doubtless been other small drainage modifications, but we note nothing as large as these. The main stream is certainly essentially in its preglacial valley, entirely across the area.

Ice Erosion.—Rock scorings or striae are found occasionally on surfaces strong enough to retain them, but usually they are very indistinct or obliterated by weathering so that little can be learned from them. Their testimony wherever found in the uplands agrees with the general evidence from New England, that the ice came from the north and moved south, and was modified in its directions locally by local elements of topography. Valleys led it here and there, hills and ridges tended to push it aside from the north-south direction. The highest hills were scored as thoroughly as any, indicating that the ice was thick enough over them to be even there a powerful agent of erosion.

It is impossible to separate the erosive work of the early ice invasions from that of the Wisconsin and almost as difficult to ascribe any drift forms to the older ice sheet, but no doubt the earlier sheets played no small part in touching up the topography and putting it in its modern form.

Several steep slopes were mentioned under Relief. Some of these are due to ice work. Perhaps the finest example of ice steepening and trimming is found in the Deerfield valley wall west and south of Readsboro. The whole valley wall here has been smoothed and very considerably steepened by the ice. No doubt preglacial river work gave it a general concave form, but the ice has trimmed, smoothed and rounded it until it looks like the wall of an amphitheater extending from the town down the valley nearly two miles. The work was done by the ice as it turned here under the directive influence of the preglacial valley form—ice from the north and northwest turned here to the southeast.

In a similar way the east and northeast sides of the hills about four miles up river from Readsboro were trimmed. The lower slope a mile above the old Davis Bridge and the big dam, on the west side of the river has been made smooth and regular by ice erosion, and above it on the county line and west of the same, on the northeast side of the hill is similar steepening. The ice certainly had trouble in the vicinity of Davis Bridge on all sides, for it has steepened all slopes some. East of the river the same smoothening and over-steepening is apparent. Even the north end of the large hill against which ice must have pushed as it came down the valley between these two steepened slopes, is by far the steepest slope of the hill.

South of Readsboro Falls both sides of the valley are over-steepened, the left bluff near the falls and the right, a mile down stream. The ice no doubt gave finishing touches to these slopes, which were already steep because of the stream transgression at this place. Again the ice pushed against the spur standing out into the valley from the west a half mile or so above Readsboro. This spur was so steepened that it could not stand and great boulders have broken loose and tumbled down the slope in gross confusion. Similarly the east bluff opposite has been steepened until in postglacial time, many boulders have split off and tumbled down toward the valley. These slopes are both very difficult to climb because of the loose huge boulders and fallen logs over them.

No doubt the steepened slope southeast of Heartwellville on the right bluff is ice trimmed also. Similar trimming shows just below Jacksonville on the west side of the first hill on the left of the valley, and opposite this to a much less extent; also about one mile farther down stream on the right and still farther down on the left. Such trimming shows the power of the ice even when a continental sheet only is present. The under part moulds itself to the valleys and hills, and trims and shapes them as it goes.

It is probable that some high level slopes have been modified also. One and one-half miles south of Howe Pond and near the western side of our area the east side of a hill has been steepened, and probably the eastern side of Jilson Hill has been similarly influenced.

Nearly all, if not all, of this work is due to scour. Plucking is scarcely known in the area. Possibly a little may have occurred near the big power plant and up-stream for a mile on the same side. Ice certainly went from north to south over this row of hills in the loop of the river, without being seriously deflected as it was in several other places. The jumble of boulders below the crests on the south side of the hills seems to indicate plucking. One or two hills just east of the area mapped, show the characteristic steep lee side as if they had been plucked also. Figure 18.

General ice erosion, including the removal of about all of the residual soil and weathered rock, was done everywhere as is shown by bare rock in scattered patches in hundreds of places and by the sharp contact between bed rock and mantle wherever the contact is exposed. Nearly all hill tops either over the top or on the least protected brow show bare rock ledges. Many acres are so thinly covered as to have but little agricultural value. Probably the largest exposures of ledges in the area are about two miles west from Readsboro. These can be seen clearly under favorable lighting for more than three miles. In several places the erosion has resulted in the leaving of furrows with rock ridges between. The furrows may be 20 to 100 feet wide and 10 to 40 feet deep and the ridges of similar size. These were first noted on the east-west road southwest of Sadawga Pond over the back of the long rounded ridge that borders the pond area on the southwest side. Here the rock ribs are 20 to 50 feet wide and nearly flat on top, also nearly bare. The troughs between them are of similar width and as much as 20 to 25 feet lower than adjacent ridges. Probably six or seven of each occur here where the road crosses them. The troughs are marshy or actually contain lakes. Essentially the same forms occur on the hill east of Readsboro in the loop of the river. The ridges and troughs are mostly larger, but are not well shown on the topographic map. They run nearly north and south. The lower troughs are well floored with drift, but the higher ones nearly as far east as the county line contain but little soil. Enough is present so that trees have grown over all. Some of the troughs are so shut in by drift as to be marshy. These troughs or furrows are undoubtedly ice carved. Every inch of their sides, and of the floor where visible, and of the ridge tops between is

PLATE XXIV.

A part of the camp, 1924. Looking east. The private road goes up the slope between the old rock wall on the left and the thick drift masses on the right. The river is 600 feet to the right or south of the road here and has not disturbed this drift at all.

smoothed and marked as by glaciers. They are in the direction of ice movement. They are similar to, but sometimes larger than, the deep furrows on Kelleys Island in western Lake Erie, which have been properly ascribed to glacial erosion.

While there has been this extensive stripping of the rock mantle everywhere, there is a remarkably small amount of really foreign material in the drift. If foreign stuff is largely present it is in the form now of sand and clay or is identical in character with our country rock. Nearly all boulders are just such rocks as occur in place in the area and near to the north. The most conspicuous foreign material is quartzite, of which there are a good many boulders. No quartzite that could have furnished these samples is known in the area nor for 15 miles to the north. It is frequently possible to map a dike of peculiar rock fairly closely on the basis of frequency of boulders. The largest dike in the area, a dark green dioritic rock, was found by tracing its boulders, and patches of marble were located once or twice by fragments in the drift. They never persist far from the outcrops.

Ice Deposition.—More significant in present topography than the erosion forms are the drift forms. A mantle covers nearly all. The drift varies in thickness from mere traces to many scores of feet. It is, in the main, thin on the uplands and thick in the valleys, thus its aggregate effect has been to subdue the relief. This is true also with reference to the placing of the drift over the slopes. In many places it has been smoothed into depressions, concavities on slopes, or against steeper slopes, and in each case so located as to round out the topography and reduce the surface relief.

In the larger preglacial valleys the drift is often very deep. In places the Deerfield was filled with it more than 250 feet. Rarely has the stream to date cut through all the drift unless it be near the valley wall so as to come down upon the wall and not in the axis of the valley. In the curve a mile above Readsboro great quantities have been smoothed into the valley so as to leave a sag between the drift and the right valley wall. Plate XXIV. Presumably a lower sag crossed the drift on the left side somewhere, for the stream now goes round the curve on that side never having modified drift forms on the opposite side. Plate XXV. The stream has encountered ledges on the outside of this curve for a few hundred feet, but nowhere else in the whole curve. The top of the drift is 200 feet higher than these ledges and may well be thicker than 200 feet in places.

Again the river is on ledges on the left side just as it goes into Readsboro, this time on the inside of the curve, and the drift is apparently fully 200 feet thick on the right side.

Drift seems to be very thick in the valleys converging on Heartwellville, but no stream has cut through it near there, so one can but guess at the thickness. Great fans have been built out into this open area by some of the streams coming into it. Much of the way West Branch flows on bed rock, but just below the half way point between the falls and Readsboro the drift is very thick and the stream has been forced to take a course close to the right side and carve a rock gorge, while a mountain of drift occupies the major part of the valley on the left side. This feature is not well shown on the topographic map.

In the central part of Whitingham township are two rock valleys draining north at present. The village is at their junction. Sadawga Pond occupies the east valley, and an arm of the big Whitingham reservoir occupies part of the other. The surface of water in Sadawga Pond is about 1,675 feet above sea-level, while that in the other valley is about 1,500 feet and yet the water is probably deeper in the latter. Apparently the western valley has not been carved much in postglacial time, for an esker nearly a mile long, lies in the valley undisturbed save by man's shovel. Certainly little erosion has occurred in the eastern valley. Probably both valleys are much as the glaciers left them except that man has enlarged Sadawga Pond and set back water from the big reservoir into the west valley. There is very little drift in the latter, while it is obviously very deep in the other. This accounts in part for the broad nearly level area under and around Sadawga Pond.

Howe Pond in the western part of the area also lies in a valley much filled with drift. The lake has been larger than at present and the stream was lowering it by cutting out the drift in the outlet, but man has now built a small stone dam and checked the process.

In the valley southwest of Lord Peak one and one-half miles southwest of Readsboro the drift is very thick, but it was not so placed as to hold water in and make a lake. Northwest of Whitingham less than two miles is a tamarack swamp not so mapped on the Wilmington sheet, but covering scores of acres. It is in a valley deeply drift-filled and partly obstructed, but left open enough to the south so it does not contain a lake. A similar distance north of Jacksonville is a filled area which is partly marshy and contains two small lakes. It is more than likely, as suggested elsewhere, that a broad valley leading southwestward was filled nearly full here.

Drift is very thin over the slopes west of Readsboro Falls from Heartwellville valley to Howe Pond. While outcrops are not at all continuous they are generally frequent over nearly this whole area. The large hill between Sadawga Pond and the river is also rather thinly covered. The slopes east of the pond and for a couple of miles southeast are also rarely more than just covered.

Special Drift Forms.—The Oberlin party worked in 1920 in the vicinity of Wilmington, Vermont, and was much interested in the special drift forms systematically deployed in that area, so it

PLATE XXV.

A few hundred feet up the private road from Plate XXIV and looking in the opposite direction. The meadow in the left and center is the mass of drift in the valley. The road is the same as in Plate XXIV following up the sag between the drift and the rock wall. The river is in the sag swinging round from the left to the center of the picture. Readsboro in the middle distance and Lord Peak, a monadnock above the second peneplain, on the sky line.

was with some disappointment that their almost complete absence was discovered in the Readsboro area. While there are moraines, eskers, and moraine terraces almost universally present in the valleys leading away from the Haystack range, testifying eloquently to the occupation of the slopes and valleys by valley glaciers after the main ice sheet was gone, in this area five to ten miles farther south there is nothing of the sort. Eskers are the only details of form left as the ice melted away.

Southwest from Whitingham about two miles, or just south of where the road from Readsboro turns north and an old dirt road leads south, there is found a well formed esker ridge. It may be seen in the road and on both sides in squares g-30 and f-31 also i-j-30. It has been opened in several places for sand and gravel, which is very abundant. The esker is a typical serpentine ridge, in some places divided, varying in height from a foot or two to about 30 feet. The road follows it southwestward. Another esker occurs in the valley west of Whitingham. This runs lengthwise of the valley for a half mile or more. It can be seen from the new road that crosses this valley between Whitingham and the big dam. The ridge of gravel occurs on the east side of the valley quite a distance south of this road in the edge of the woods, and with a winding course leads northward until it goes below the water on the west side of the valley, some distance north of the road. It has been extensively opened for gravel.

Eskers are the beds of subglacial streams built by aggrading waters in a tunnel under a waning glacier. Presumably there is very little or no flow of ice, else a serpentine ridge would be disturbed and mussed. Thus an esker in good form is no evidence of local glaciers for they are made after the ice sheet ceases to flow actively, and during the final melting of the ice.

In the main valley are found some gravel and sand deposits laid by waters from the melting ice. Small deposits in two or three places around Readsboro still show. Larger masses occur up stream a mile or two now carved into terraces. These are around the adit and especially opposite. Other gravel deposits were made and preserved in the turn of the valley two miles above the Davis Bridge. These were subsequently carved into terraces and were mapped in 1920, but the water of the big reservoir covers them completely. It is probable that outwash gravels were laid all the way down the valley from the moraines near Wilmington to Massachusetts and farther, and that the patches we now find are remnants of them, left after the streams have been operating upon the deposits through all postglacial time.

Postglacial Stream Work.—As the ice withdrew foot by foot, the streams took possession. Thus they have operated longer in the southern than in the northern part. The area is so narrow, however, that the difference in time is short, and is not perceptible in erosion forms. In fact all postglacial time measured in terms of what has been done by streams is short.

To appreciate its brevity note that outwash has not been removed entirely in the valleys, hence valleys are not even as deep and wide as they were before the ice came. Eskers still remain in some valleys. Drift forms occur just as the ice left them in several places in valleys, showing that the streams have not yet had time to clear out the material the glaciers put into their old valleys. Falls and rapids and steep grades, in all stream beds still persist. Lakes are undrained, even unfilled as yet. Marshy tracts still interfere with agriculture, but when drained they may contribute acres of rich black soil. Water power is still a great asset and will be for ages to come.

But with so much not done it is worth while to observe what has been done. Where opportunity offered some streams have carved deeply into drift. Witness the deep cuts near Readsboro and a mile up-stream and others on the West Branch. The falls up this West Branch have only receded a short distance. They seem to have begun as rapids and hence had little or no gorge at the start. They are no doubt related to the stream diversion here, discussed elsewhere. Potholes have been made in great numbers in the bed rock for a couple of miles below Readsboro Falls. Some are large enough for a bath tub, others are but inches across. Potholes are notable features in most streams that are on bed rock, but the schist in this particular area lends itself to pothole carving more readily than most of other rocks.

In general the streams occupy preglacial valleys and have done relatively little toward adjusting to them. Rapids and more level reaches alternate on all streams but the main one. In that the grade is fairly uniform, but in the scores of little laterals the grade is very variable and vastly greater than in the Deerfield. Valley floor slopes of 300 to 500 feet per mile are common in the laterals, while 20 to 40 feet per mile is about the range in the large river.

Streams are not in the centers of valleys in many cases. Howe Pond is fairly symmetrically placed with reference to the contours near it, but with reference to higher contours it is close to the north side of its valley. Drift is thick on the southern slopes, filling in and crowding the lake over. In like manner its outlet is not centrally placed. It is easily four or five times as far from the 2,000 foot contour on the south side as from the same on the north. The same asymmetry with reference to higher lines is obvious. Even the Deerfield is far to one side of its valley in some places. In the northern half of the area where it flows in general southward the eastern slopes or valley walls are generally much gentler and all but the lowest lines are much farther from the stream on the east side. In the vicinity of the big dam the symmetry is notable, but below the adit the lack of symmetry is just as striking. Drift deposition certainly has something to do with this, and the large curve in the river through Readsboro has been an important factor.

Nearly all the smaller streams have in their upper courses practically no valleys yet. Postglacial time has been so short that only channels have yet been made and some of these are quite inadequate. So far then as preglacial valleys are concerned, drainage is good, but where drift has interfered, postglacial work is so immature that drainage is really very poor.

The events of the glacial period kept the streams from the main job while the glaciers were here and left a little drift in the way of immediate resumption of the normal work, but after all one must look upon the whole problem of the glacial period as an extremely ephemeral item as compared with the work of base leveling the region after a 1,400 foot uplift. It caused but a momentary interruption for the streams, an interruption which is now nearly over, for the streams are already touching the rocks in places and the ice is long ago all gone.

Each stream began its postglacial task by removing drift from the preglacial valleys, preparatory to a new attack on the rocks. So short has postglacial time been that most of the streams are still at this preliminary work. Great tasks are ahead if the valleys are all to be made mature or old, and the region reduced to a peneplain near the new sea-level. The removal of the drift from the valleys is but the merest trifle compared with the greater task.

With the land so high as it now is above sea-level—its base-level—active erosion is unavoidable whenever and wherever water can run. A continuation of the drift removal, associated with and followed by rock excavation to the maximum depths will follow now. Then will come the widening of valleys, development of flood plains, tributary valleys and finally the attack of divide areas until the ultimate stage of erosion shall have been reached—the peneplain with a few monadnocks. With this vision of the task ahead it is obvious that postglacial erosion to date is very meagre.

Weathering, erosion, transportation are the chief geologic processes in operation here now. Sedimentation ceased long ago. Diastrophism is not now apparently in operation. Vulcanism, metamorphism and folding are not in play. There is no guarantee that any or all of the processes may not some day again become active. We simply can say that at present they are inactive and streams are free to carry on their work uninterrupted.

ECONOMIC RESOURCES.

Prospects for Metallic Minerals.—In spite of a good deal of of interest, not to say mild excitement over possible wealth in metallic ores in the Readsboro region, it seems necessary to state that the place has no promise of importance in this direction.

Gold and silver so ardently sought at times by man are not to be found here in workable quantities. Traces of the former have been found, fake assays have made disturbing returns, but the stern fact remains that more money has already been put into the gold and silver mining business of this little region than has ever been taken out or is liable to be taken out, no matter how much may yet be invested.

Copper and nickel have also been reported, but are only available as curiosities in the scantiest traces. Iron, the metal above all metals, in man's requirements today, only occurs in one ore mineral, magnetite, and that only in scattered tiny crystals absolutely unworkable. The sulphides of iron, pyrite and rarely pyrrhotite are also widely scattered, but they are never considered an ore of iron even when concentrated, and this region cannot possibly enter the market. A few masses of pyrite have been found in the drift, notably one or two up Readsboro Falls road about a mile above Readsboro, but these occurrences should never excite the finder. They have no commercial value.

Aluminum has been said to occur here. The statement properly qualified is true. Aluminum is a constituent of all micas and feldspars which are common nearly all over the area. It is also a part of all clays and the glacial drift. Chemists can get this aluminum out and make sheet or bar aluminum of it, but it is not a large ingredient of these substances and cannot be extracted and put on the market to compete with that taken from the aluminum ore, bauxite. Bauxite does not occur in the region.

There is no metal that can be extracted with profit, to be found in our area. The chief values with geologic connections are soils, water, and water power, building and road materials, gravels and sands.

Soils.—Soils are largely glacial drift and are of good quality and long life. Some are so free from limestone that they become a little acid. Two conditions should be considered in selecting a soil. 1, Its physical condition, thickness, stoniness and tilth; 2, its water—drainage and washing or eroding are the vital items. Does it drain well so it can be cultivated early in the spring, and promptly after rain? Does it lie so as to wash badly by running water? There are small areas where the soil is too thin or too stony, but most of the area is covered with mantle enough to serve agricultural purposes. Larger areas are too wet, some even boggy, and many patches are springy above so that they receive seepage and are constantly too wet to cultivate. A few slopes are too steep and rocky and should be left in forest. But these soils unusable are really only a small area. Much land can actually be plowed, larger areas should be in grass to mow, and probably still more should be in grass for pasture, while forests, sugar bushes, and game preserves should take the rest.

Water Supply and Power.—The rainfall is ample and usually well distributed, but if three or four weeks of the growing season do go by with scanty rains the hay and crops suffer more than they do in regions with a heavier clay soil. Springs are frequent and serve most of the country homes abundantly. Streams are frequent and where too large a village has grown up to be supplied with spring water. Some small streams can be ponded back to serve the community. The ponding of waters for power purposes is a common practice. Formerly most of the small streams were made to serve, but now most of the small powers have been abandoned and large plants are built on the main streams as frequently as the fall permits. The whole problem of the river is surveyed. All fall is considered, all possible storage basins are measured and all sites for dams scrutinized, then selection is made of the best site to use the most power. Nearly every generation has improved on the work of its predecessors in the conservation of power. At present one large plant in the Deerfield valley about three miles up-stream from Readsboro monopolizes essentially all the power on the main stream in our area, and up-stream four or five miles farther. This project takes the water from the stream three miles above Readsboro at the big dam, which is 180 feet high, and conducts it two and one-fourth miles through a tunnel and returns it over wheels at the foot of great penstocks, to the stream two miles below Readsboro, concentrating in one fall and power plant nearly all the fall of the stream for twelve miles. Sadawga Pond, enlarged, serves as a subsidiary reservoir for the same power plant. Howe Pond is used as a water supply for the village of Readsboro.

Building and Road Materials.—The materials for building and roads are abundant. Some of the marble could be used for building, but most of it is too badly fractured, and too rich in micas and other accessories due to its mixed sedimentation and its metamorphism to make suitable building stone. In several places the schists are cleavable and could be quarried. One such place is near the railroad station at Readsboro, and also below the local dam in the gorge. Here the stone is a gray quartz-mica schist and could be gotten out in considerable quantities. Other occurrences are farther from town and the railroad, but there are several places that could be opened up. Road materials have included, until recently very little but the gravels and sands, but there are quantities of mica schists which can be crushed and spread on the roads and dressed with a little crushed marble as a binder, making a very fine road. This schist is beginning to come into use and no doubt will become more and more significant. It can be gotten out with steam shovels in places beside the road, preceded if necessary by blasting, crushed and put right on the road with no serious difficulties of any sort.

The topography is mature enough to make road building and maintenance a fairly simple matter. Lines can be laid out with so low a grade that travel is easy and washing nearly impossible. Of course some roads up to scattered farm houses present larger difficulties, but ways are being found now to get out and in over an easy grade from almost every occupied house.

Gravels and sands are generally along the present or ancient streams. One of the finest sand banks of the area is opened in an esker a half mile south of the main road from Whitingham to Readsboro, leaving the main road at the turn marked "Readsboro three miles." Referring to the system of squares this esker is in f-g-30-31-32 along the diagonal, woods road. Another esker occurred in the valley running north and south, west of Sadawga Pond. It has been extensively worked and part of it is now under water. East of the first esker mentioned are several short sections of esker, probably parts of the same subglacial drainage system, which could be used for sand or gravel, but so far have not been opened.

Sand and gravel can often be gotten in places along some of the present streams in outwash deposits made by glacial waters during the waning of the ice sheet. There is, however, no adequate supply of either sand or gravel and most of it is not well enough sorted to be very valuable.

The marble mentioned as a poor building material has a larger use as a corrective for acid soils. It is quarried and crushed and put on the land and allowed to do its work—neutralizing the acid. Good effects have been shown to follow its use for 20 years. It has been burned both for lime for plaster, and for soil dressing. The former use is probably a thing of the past, but as a soil dressing it is much more active and quicker in its effects than the crushed rock. Much more use of the marble could and probably should be made as a medicine for soils.

The marble at Sherman has been shown by actual use to be valuable for the manufacture of calcium carbide. During the early part of the war a plant for its manufacture was constructed at Sherman at a large cost. A very excellent product was made for six or eight years, but about a year ago the plant shut down and now it is being dismantled. There seems to be no local reason why the process should not be successfully carried forward. But the place is some distance from a coal supply and out on a stub railroad expensive to operate and these things are handicaps. On the other hand the plant is far enough from industrial centers to have little or no detrimental contacts with the large labor problem. Further, the product is claimed to be very superior. The marble is abundant and very easily gotten from quarry to plant. The geologic and geographic conditions may be considered very satisfactory.

When all is said that can be said for the geologic resources of this region, it has to be admitted that there is no foundation for any considerable industrial development. Water power is

abundant and is transmitted far, and not much used on the ground. By all odds the most promising industry is agriculture in its several phases, dairy and beef cattle, sheep, hogs, poultry, hay, potatoes, apples, maple syrup and other subsidiary branches. The Vermonter has long lived happily and successfully in this region and there is yet a fine opportunity for just as valuable a human occupation of the valleys and slopes.

MINERAL RESOURCES.

G. H. PERKINS.

The age-old saying, "Line upon line, precept upon precept," seems still needed in Vermont so far as concerns metals and coal.

Over and over again in several former Reports the Geologist has tried to emphasize the facts respecting Vermont minerals, but many samples of supposed ore (they are more frequently thought to indicate gold than other metal) come to this office during the year.

People should remember that for more than a hundred years the small area of the State has been diligently searched for metal deposits of such size as to warrant the expense of developing, without favorable result, although in some cases a not inconsiderable amount of money has been put into holes from which nothing, or very little, of value, could be taken out.

It is also to be remembered that in the whole history of mining in Vermont not a single mine, though many have been worked, has ever been a paying proposition for any length of time. A very few have, for a longer or shorter time, paid more than expenses, but none for long and by far the greater number have given no return but have proved a total loss.

Metals of various sorts are to be found in Vermont, but always in so small quantities that the vein, mine, or whatever, was of no value. We have every scientific reason to predict that no such deposit of metal, as would warrant the expense of development, will ever be found in this State and that, this being true, there is no use in trying to find it.

As to coal, the geological conditions in Vermont are such that coal cannot be found here. The reason being that coal is formed from deposits of vegetable matter and when the rocks of Vermont were deposited, vegetation such as was necessary to supply material which, under proper conditions, would form coal could not exist, and did not for ages after.

I do not forget that these facts have been published in former Reports, but, as already indicated, it seems necessary to repeat them.

Always the mineral wealth of Vermont must be limited to quarries. The only mines in Vermont, the only sort there can be, are those producing talc.

Asbestos, found in several localities, has been very thoroughly exploited in this State, but has so far nowhere proved profitable and all the asbestos mines are now closed. Talc will be considered later.

As for several years past, Vermont leads this and, I believe, all countries in the value and production of granite and marble, and in the United States is second, though not a very close second, in slate to Pennsylvania.

GRANITE.

As everyone acquainted with the granite business in Vermont knows, it is mainly confined to a few localities, all east of the Green Mountains, and at each of these localities there are a greater or lesser number of companies. The Barre district, Woodbury, Hardwick, and Montpelier, are the more important localities, while at Waterbury, Northfield, South Ryegate, Groton, Barton, Concord, Bethel, Newport and several other towns there are, or have been recently, granite quarries and cutting sheds in operation. In these places there are, as will be seen from the lists below, a large number of companies—much larger than of all other stone-working companies combined.

By comparing lists of these companies one will notice that from year to year there is considerable change in the personnel or, at least, in the firm name; old companies disappearing, new ones formed. On this account frequent revision of the lists is needed.

The lists given below, while possibly not without error, are nearly so. In preparing them I have been greatly aided by Mr. B. E. Mitchell, Secretary of the Granite Manufacturers Association of Barre, also by the Woodbury Granite Company for Hardwick and Woodbury and others.

Of the Barre companies the larger number are non-union, though between thirty and forty are in the Union. How this is elsewhere I am not able to say.

At times during the last two years, because mainly of labor troubles, the granite business has been somewhat irregular, but it is reported as on the whole pretty good.

I am not able to give the average value of all sales of granite, rough and dressed, for the last five years, but, approximately, they have been from $3,500,000 in poor years, to $6,500,000 in the best years. This gives for an average $5,500,000, which I think is less than is the true amount for the whole State.

LIST OF GRANITE COMPANIES IN VERMONT, 1924.

Barre District.

NON-UNION COMPANIES.

Aja Granite Co., U., Montpelier.
Anderson-Friberg Co., Inc., Barre.
Anderson & Johnson, Barre.
Arioli & Co., G., Montpelier.
Barclay Bros., Barre.
Barre Granite Mtl. Wks., Montpelier, Q.
Barre Memorial Co., The, Barre.
Batchelder & Co., Inc., E. J., Barre.
Beck & Beck, Barre.
Bellucci Granite Co., A., Montpelier.
Bilodeau & Co., Inc., J. O., Barre.
Bond Gr. Co., Inc., George E., Barre.
Boutwell, Milne & Varnum Co., Barre, Q.
Brown & DeMerell, Barre.
Brusa Bros., Barre.
Burke Bros., Barre.
Buzzi Granite Co., Barre.
Canizo & Co., E., Barre.
Canton Bros., Inc., Barre.
Capitol Granite Co., Inc., Montpelier, Q.
Carroll Bros., Barre.
Carswell-Wetmore Co., Inc., Barre.
Caslani Bros., Barre.
Celente & Bianchi, Barre.
Chioldi Bros. Granite Co., Barre.
Cole & Son, William, Barre.
Columbian-Artistic Gr. Co., Montpelier.
Cook & Watkins Mfg. Co., Inc., Barre.
Comolli & Co., Barre.
Cross Bros. Co., Inc., Northfield.
Davis Bros., Inc., Riverton.
Debitetto & Caccavo, Barre.
Dessureau & Co., Barre.
Doucette Bros., Montpelier.
Desilets Granite Co., Inc., Montpelier.
Eastern Granite Co., Montpelier.
Eureka Granite Co., Inc., Montpelier.
Excelsior Granite Co., Montpelier.
Freeman & Wasgatt, Barre.
Gelpi Granite Co., Barre.
Genest & Beaulieu, Inc., Barre.
Gill & Co., C. P., Montpelier.
Giudici Bros. & Co., Barre.
Glysson & Co., Inc., E. C., Barre.
Grearson & Lane Co., Inc., Barre.
Green Mountain Granite Co., Montpelier.
Harrison Granite Co., Barre.
Hebert & Ladrie, Barre.
Hedwall & Co., Inc., Paul, Barre.
Higuera Granite Co., M., Montpelier.
Hinman Co., Inc., H. P., Barre.
Industrial Granite Co., Barre.
Johnson Granite Co., The, Montpelier.
Johnson & Gustafson, Barre.
Jones Bros. Co., Inc., Barre, Q.
Jurras Granite Co., Inc., Montpelier.
Kent & Russell, Inc., Barre.
LaClair & McNulty, Inc., Barre.
LeClerc, R. A., Montpelier.
Lillie Granite Co., Inc., Montpelier.
Littlejohn, Odgers & Milne, Barre, Q.
Lucie Granite Co., Montpelier.
Marr & Gordon, Inc., Barre.
Marrion & O'Leary, Inc., Barre.
Menard & Erno, Montpelier.
Mills & Co., Montpelier.
Milne Granite Co., The Wm., Barre.
Mutch & Loranger, Barre.
McDonnell & Sons, Inc., Barre, Q.
McGovern Granite Co., Inc., Barre.
National Granite Co., Inc., Montpelier.
Nelson & Mattson, Barre.
Newcombe, Thomas J., Barre.
Novelli & Calcagni, Inc., Barre.
O'Clair Granite Works, C. L., Waterbury.
Olliver Granite Co., Barre.
Olson & Nelson, Barre.
Pando Granite Co., Northfield.
Parnigoni Bros., Barre.
Parry & Jones Co., Inc., Barre.
Peerless Granite Co., Barre.
Pelaggi & Co., Inc., Northfield.
Perry Granite Corporation, Waterbury.
Phillips & Slack, Inc., Northfield.
Pirie Estate, Barre, Q.
Pratt Granite Co., Inc., Barre.
Provost Granite Co., Inc., Riverton.
Puente Granite Co., Barre.
Redmond & Hartigan, Barre.
Rissi & Son, Barre.
Robertson, J. C., Barre.
Robbins Bros., Barre.
Ross & Ralph, Barre.

Roux Granite Co., Barre.
Russell & Brand, Barre.
St. Onge & Son Granite Co., Montpelier.
Saldi, Rossi & Co., Barre.
Sanguinetti, A., Barre.
Saporti & Co., Wm., Barre.
Sector & Co., James, Barre.
Sheridan & Poole, Barre.
Sherra Granite Co., R., Barre.
Smith, E. L. & Co., Barre, Q.
South Barre Granite Co., Inc., Barre.
Standard Granite Co., Barre, Q.
Straiton, George, Barre.
Star Granite Co., Montpelier.
Tosi & Co., E., Barre.
Union Granite Co., Barre.
Union Granite Co., Inc., Waterbury.
Usla & Revilla, Barre.
Valz Granite Co., Barre.
Vermont Manufacturing & Quarry Co., Barre, Q.
Victory Granite Co., Barre.
Wells & Lamson Quarry Co., Barre, Q.
Wetmore & Morse Granite Co., Barre, Q.
World Granite Co., East Barre.
Young Bros., Inc., Barre.
Zorsi & Co., G., Barre.

UNION COMPANIES.

Alonzo & Aja, Barre.
Abbiatti & Fontana, Barre.
Bianchi & Sons, Chas., Barre.
Canales & Gomez, Barre.
Central Granite Co., Barre.
Crescent Granite Co., Barre.
Carley & Cummings, Barre.
Cedrone Granite Co., Barre.
Cenci & Bardossi, Barre.
Eagle Granite Co., The, Barre.
Gerard & Barclay, Barre.
Gomez Bros., Barre.
Hoyt & Milne, Barre.
Imperial Granite Co., Barre.
Liberty Granite Co., Barre.
Lawless Granite Co., Barre.
Martinson Estate Co., Barre.
Modern Granite Co., Inc., The, Barre.
McColl & Abare, Barre.
North Barre Granite Co., Barre.
New Starr Co., The, Barre.
Orlandi, A., Barre.
Parnogoni, B. & Co., Barre.
Rosa Co., F., Barre.
Ravilla Granite Co., J., Barre.
Shield & Co., Waldron, Barre.
Steele Granite Co., Barre.
Twentieth Century Gr. Co., Barre.
United Granite Co., The, Barre.
Vanetti Granite Co., Barre.
Valdivielso & Esteran, Barre.
Webster Granite Co., Barre.
Bettini & Ratazzi, Barre.
Barre Granite Co., Barre.
Bardossi Granite Co., Barre.
Corskie Co., J. P., Barre.
DeRegibus Granite Co., Barre.
Dunghi & Groppelli, Barre.
Fontana, E., Barre.
George Granite Co., Barre.
Gomez, Lang, Pena Bros., Barre.
Hastings Granite Co., J., Barre.
Lawson, Alex., Barre.
Lion Granite Co., Barre.
Lorenzini, C., Barre
Milne, Alex & Co., Barre.
Movalli & Co., J., Barre.
Nicora Granite Co., A., Barre.
Native Granite Co., Barre.
Palaoro Bros., Barre.
Rex Granite Co., Barre.
Rossi, Granite Co., Barre.
Rabaloli & Rossi, Barre.
Sartell & Grierson, Barre.
Simonelli & Fontana, Barre.
Usle & Parajo, Barre.
Verd Mountain Gr. Co., Barre.
Venetian Granite Co., Barre.
Williamstown Granite Co., Barre.
Zampieri & Buttura, Barre.

America Granite Co., Montpelier.
Everlasting Gr. Co., The, Montpelier.
Liberty Granite Co., Montpelier.
Pellon Granite Co., I., Montpelier.
Bonazzi & Bonazzi, Montpelier.
Doyle Gr. Co., M. J., Montpelier.
Ortiz Granite Co., Montpelier.

Politti Granite Co., Northfield.

Montpelier—See Barre District.
Northfield—See Barre District.
Waterbury—See Barre District.

Hardwick and Woodbury.

Ambrozini & Co., M., Hardwick, Quarry at Woodbury.
American Granite Co., Hardwick, Q.
Bailey, Geo., Hardwick, Q.
Calderwood, Fred., Hardwick.
Carter Granite Quarries, Inc., Mackville.

Couhig, M. J., Hardwick.
Crystal Brook Granite Co., Hardwick.
Eureka Granite Co., Hardwick.
Fletcher, E. R., Woodbury, Q.
Good, P., Hardwick.
George & Somes, Hardwick.
Govaraldi & Co., G. V., Hardwick.
Hay, John, Hardwick.
Hardwick Polishing Co., Hardwick.
James Granite Co., Hardwick.
Kennedy, J. A., Hardwick.
Nunn & Fordyce, Hardwick.
Murch, E. R., Hardwick.
Purdy, F. A., Hardwick.
Robie, L. S., Woodbury, Q.
Ralph & Co., Geo. Y., Hardwick.
Taylor, Alex., Hardwick.
Thomas, A. B., Woodbury, Q.
Woodbury Granite Co., Hardwick, Woodbury, Q.

GROTON.

Groton Quarry Co., Q.
Hendry & Mille.
Hendry, C. H.
Hosmer Bros.

SOUTH RYEGATE.

Blue Mountain Granite Co., Q.
Newbarre Granite Co., Q.
Ryegate Granite Works Co., Q.

BARTON.

Barton Granite Co., Q.
Crystal Lake Granite Co., Q.
Lewis, L. R.
Roy Monumental Works.
Roy, T. F.

CONCORD.

Lillecrop & Son.
Moose River Granite Co.
Smith Granite Co., L. E.

ADAMANT.

Hughes Granite & Quarry Co., Q.
Orzella, Frank & Mazzi, Frank.
Steele Granite Co.
Shields, Waldron.

OTHER LOCALITIES.

Haselton, C. S., Beebe Plain.
Stansted Granite Quarry, Beebe Plain.
Presby Granite Co., Leland, Dummerston, Q.
Newport Granite Co., Derby, Q.
A. J. Goss, West, Danville, Q.

In the above lists those marked Q. have quarries. The others manufacture the rough stock from quarries.

MARBLE.

Although marble is more widely distributed over the State than other building stone it is found mainly only west of the Green Mountains.

Nearly all worked quarries are located in Rutland County and are worked by a few companies, as follows:

Clarendon Marble Company, Clarendon.
Eastman Marble Company, Rutland.
Vermont Marble Company, Proctor, main office.

All the above have quarries and manufacturing plants.

Probably there is nowhere a marble company as large as the Vermont Marble Company which has mills and offices in—beside the headquarters in Proctor—Rutland, West Rutland, Florence, Middlebury and elsewhere. Quarries at Proctor, West Rutland, Florence, Brandon, Danby, Dorset, Swanton, Isle La Motte, Rochester, etc.

A full account of the marble industry in Vermont from its early days may be found by anyone, especially interested, in the Ninth Report of this series, which can be obtained at the State Library.

The total value of the marble sold in Vermont varies from year to year, but is not less than $4,000,000 to $5,000,000.

SLATE.

The third great stone industry in Vermont is the production of slate.

The productive slate region of the state is, like the marble area, mostly in Rutland County, west of the marble and it extends into the State of New York. In some cases the quarries are at least partly in one state and the business offices in the other.

East of the Green Mountains, especially in Northfield, there are quite extensive beds of slate, but they have not been continuously worked.

The following is a list of slate companies at present producing:

LIST OF SLATE COMPANIES.

CASTLETON.

P. F. Hinchey and Company, Hydeville. Quarries. Mill stock only. Colors green, mottled and purple.
Penrhyn Slate Company, Hydeville. Quarries. Mill stock only. Hydeville Plant, Lake Bomoseen Plant, Scotch Hill Plant. Mottled, green and purple.
Hydeville Slate Works, Hydeville. Mill stock only. Mottled, green, purple.
John Jones Slate Company, Castleton. Quarry. Mill stock only. Mottled, purple.
Lake Shore Slate Company, West Castleton. Quarry. Mill stock only. Mottled and purple.

FAIR HAVEN.

Clark and Flanagan Slate Company. Quarries. Mill stock and roofing. Unfading green, purple, mottle, gray.
Durick, Keenan and Company. Quarry. Mill stock only. Mottled and purple.
Eureka Slate Company. Quarries. Roofing slate. Unfading green, mottled, purple.
Fair Haven Marble and Marbleized Slate Company. Quarry. Mottled purple, green.
Locke Slate Products Corporation. Mottled, green and mottled purple.
McNamarra Brothers Slate Company. Electrical slate only.
Mahar Brothers Slate Company. Quarries. Mill stock and roofing. Mottled, green and mottled purple.
Old English Slate Company. Quarry. Roofing. Mottled and purple. Office, Boston, Mass.
W. H. Pelkey Slate Company. Quarry. Roofing. Green.
Vermont Milling and Products Corporation. Ground slate only for roofing. Mill at Poultney; Office, Fair Haven.
A. B. Young Slate Company. Mill stock only.

POULTNEY.

Auld and Conger Company. Quarries in Vermont and Pennsylvania. Roofing. Weathering green, unfading green, sea green, purple, mottled.
Donelly and Pincus Slate Company. Quarries. Roofing. Unfading green, purple, mottled.
General Slate Company. Quarries. Roofing. Sea green, mottled, purple, gray.
United Slate Co. Roofing. Mottled.
Vendor Slate Company. Quarries. Roofing. Sea green, mottled, purple, gray and unfading.
Staso Milling Company. Ground slate only.
New York Consolidated Slate Company. Quarries. Roofing. Green, purple, unfading green, mottled.
F. C. Sheldon Slate Company. Quarries. Roofing. Purple and sea green.

WEST PAWLET.

Rising and Nelson Slate Company. Quarries. Roofing. Sea green.

WELLS.

O'Brien Brothers Slate Company. Quarries. Roofing. Purple and sea green.
Burdette and Hyatt. Quarries in Wells; Office in Whitehall, N. Y.
Norton Brothers Slate Company. Quarries in Vermont and Granville, N. Y.; Office in Granville, N. Y. Roofing. Green, purple, red.
O. W. Owens and Sons Slate Company. Quarries in Vermont and New York; Office in Granville, N. Y. Roofing. Green, purple, red.
Progressive Slate Company. Quarries in Vermont and New York; Office in Granville, N. Y. Purple, green, red.
F. C. Sheldon Slate Company. Quarries in Vermont; Office in Granville, N. Y. Roofing. Sea green.
Vermont Slate Company. Quarries in Vermont; Office in Granville, N. Y. Sea green, purple, red.
H. G. Williams Slate Company. Quarries in Vermont and New York; Office in Granville, N. Y. Roofing. Purple, red, green.

During the last few years the amount of slate shipped from Vermont has increased and is now not less than $4,000,000.

TALC AND SOAPSTONE.

As those who have read the Geological Reports immediately preceding this have noticed there has been considerable fluctuation in the amount of talc sold in Vermont during different years. Of late this has increased.

The companies producing this material in Vermont are as below:

LIST OF COMPANIES PRODUCING TALC.

American Mineral Company, Johnson.
Magnesia Talc Company, Waterbury.
Eastern Talc Company, Main Office, International Trust Co. Building, Boston, Mass. Mines, East Granville, Rochester.
Vermont Talc Company, Chester Depot.

SOAPSTONE.

American Soapstone Finish Company, Chester Depot.

LIME AND LIMESTONE.

Very little limestone to be used in building is sold in Vermont. Most of what is quarried is burned to quicklime. The value of such lime sold in the State amounts to not less than $500,000.

A list of Vermont companies that are now, or have recently produced lime are as follows:

LIST OF LIME KILNS IN VERMONT.

Amsden Gray Lime Company, Amsden. This company has been continuously active for many years. Of late, however, it has taken several important steps forward, involving considerable new machinery and will soon, if not already, be able to add largely to its output. Besides abundance of limestone, the company owns large tracts of woodland from which to obtain fuel and material for barrels.
Missisquoi Lime Works, Highgate Springs.
Fonda Lime Kilns, St. Albans.
Swanton Lime Works, Swanton.
Champlain Valley Corporation, Winooski.
Green Mountain Lime Company, New Haven Junction; Office, Worcester, Mass.
Brandon Lime and Marble Company, Leicester Junction.
Vermont Marble Company, Proctor.
Pownal Lime Company, Pownal; Office, 92 State St., Boston, Mass.

INDEX.