REPORT

OF THE

STATE GEOLOGIST

ON THE

MINERAL INDUSTRIES AND GEOLOGY

OF

VERMONT

1927-1928

SIXTEENTH OF THIS SERIES

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State Geologist

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STATE OF VERMONT

OFFICE OF STATE GEOLOGIST

BURLINGTON

DECEMBER 1, 1928.

To His Excellency, John E. Weeks, Governor:

Sir—In accordance with Act 405 of the General Laws of Vermont I herewith present my Sixteeth Report as State Geologist.

The work carried on by the Vermont Survey is indicated in detail in the Introduction which follows.

As will be seen by examining the following pages, a large part of this volume is occupied by articles which treat of the surface and physical features of the State. The occurrence of the Great Flood of November, 1927, causing especial study of methods of flood control has very strongly emphasized the necessity of a complete knowledge of the surface features of the State, or at any rate as complete a knowledge as can be attained, since only by this means can future disasters be prevented. It is, therefore, with great satisfaction that the Geologist has been able to secure the services of several very competent Geologists who have devoted much time to the investigation of the physical features of Vermont. Several of the following articles give the results of this investigation.

It is expected that these studies may be continued and the results given in the next Report.

Respectfully submitted,

GEORGE H. PERKINS,

State Geologist.

INTRODUCTION

A brief summary of the contents of the following pages must suffice as introduction. Dr. Elwyn L. Perry of Williams College presents in the first article a carefully worked out account of the Geology of Plymouth and Bridgewater, Vt. The complex features of the rocks found in many parts of the State are well illustrated by the outcrops found in these towns.

In the second article Professor F. A. Burt gives the result of several seasons' study of the beds of Kaolin found in the Bennington area and discusses in a very satisfactory manner the origin of these clays.

This is followed by an account of the various sorts of rock found in Vermont by the State Geologist. This paper is made as free from technicalities as possible, as it is intended not so much for specialists as for the enquiring high school student. In the fourth article Professor C. H. Richardson gives an account of the Petrography of the Irasburg Conglomerate, a formation which he first made known and has studied for several years.

The fifth article by the State Geologist is an account of the Topographic maps of Vermont made by the U. S. Geological Survey in cooperation with the State. This is followed by as complete a list as can be made at the present time (and it includes most of the area of Vermont). A large part of this list, though by no means all, has been published in former Reports, but, aside from extensive additions, the fact that all the older Reports were badly damaged during the flood of 1927 so that only imperfect copies can now be supplied and of several none at all, it has been thought best to give in this volume as complete a list of all elevations as possible in such form as is most convenient to those who desire the information which may be found in the list.

In the next article Professor Richardson continues his investigation of the rocks of the eastern portion of the State which, beginning at the Canada Line, he has during many years carried south until in the present paper he reaches Cavendish, Chester, etc. Following this Professor B. F. Howell gives the result of investigations of the rocks of St. Albans and vicinity, especially on Cambrian beds of the region. Mr. Foyles, who, for several years has been studying the formations of western Vermont, continues his report of work in the two papers that follow, taking up Ferrisburg in the first and a wider area in the region in the second. The petrography of the dikes of this area is discussed by Professor H. L. Alling. Two articles, which give the results of careful study of the surface features of parts of the State are Miss Adela M. Pond's paper on "The Peneplanes of the Taconic Mountains of Vermont," and the paper by Professor H. A. Meyerhoff and Miss Marion Hubbell on "Erosional Landforms of Eastern and Central Vermont." There is much in these papers which is of very great value to any who study the problem of flood control which the recent flood has brought so forcibly to the attention of the people of this State.

Finally there is a brief report on the present Mineral Resources of the State.

THE GEOLOGY OF BRIDGEWATER AND PLYMOUTH TOWNSHIPS, VERMONT

Elwyn Lionel Perry

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INTRODUCTION

This paper describes the lithology, areal distribution, structure and probable origin and history of the geological formations found in the townships of Plymouth and Bridgewater, Vermont. Particular interest is attached to the rocks of this area since they comprise the lower or older part of an important series of metamorphosed sediments of Central Vermont, the younger members of which have been the subject of long continued study by Dr. C. H. Richardson of the Vermont State Geological Survey. The older members have heretofore never received adequate study and description.

The principal field work upon which this study is based, was carried out during the summer of 1925 under the auspices of the Vermont State Geological Survey. The writer is particularly indebted to Dr. Richardson for his assistance in the field in the month of June, 1925, and for his criticisms and suggestions dur-

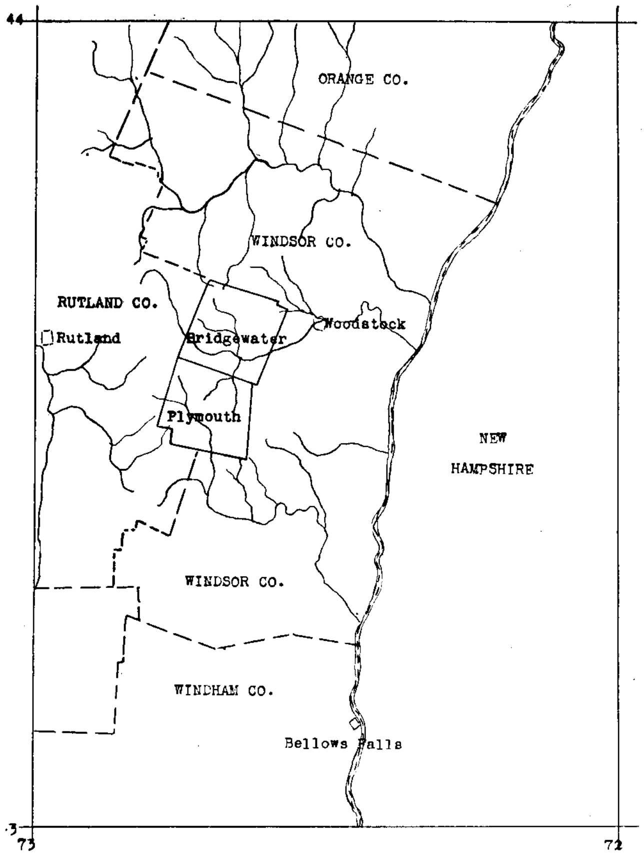

FIGURE 1.—Map of the Area Discussed.

ing the preparation of this report. Thanks are extended to the members of the Department of Geology of Princeton University for their advice and assistance in the study and interpretation of the results of the field work.

LOCATION OF THE AREA

The townships of Plymouth and Bridgewater are located in central Vermont, midway between White River Junction and

Rutland about fifteen miles east of the latter city and fifty miles north of the Massachusetts border. The main range of the Green Mountains extends, with a north-south trend along the western edge of the towns. The area is largely included in the Woodstock quadrangle of the U. S. Topographic Atlas, but portions of western and southwestern Plymouth are included in the Rutland and Wallingford quadrangles respectively and most of the southern part of Plymouth is unmapped. The total area included in the two towns is about one hundred square miles.

PREVIOUS WORK IN THE AREA

Several geologists, especially during the latter part of the last century, have found the geology of Plymouth to be worthy of interest, but in all except one case, observations were confined to special phenomena rather than to a systematic study of the entire area. The mineral deposits of economic value have received the most attention, but the metamorphosed conglomerate of Plymouth also received considerable comment, particularly by Edward and Charles Hitchcock.

In 1861, A. D. Hager in collaboration with Edward Hitchcock and his sons, published a geological map of Plymouth and a very brief description of the geology. This map represents the only systematic work done on the geology of the region up to the present time. Very little differentiation of the formations was attempted by Hager, and although his map is correct in its broadest aspects, the detail is unreliable. The principal authors who have described some special phase of the geology of the region are: the Hitchcocks, Edward, Charles and Edward, Jr., who in several papers have discussed the glacial phenomena, the significance of the metamorphosed conglomerate, the gold deposits and other less important features; Dr. T. N. Dale, who has described the granite and dolomite of Plymouth; Dr. C. L. Whittle, who has studied the Pre-Cambrian rocks of western Plymouth; Dr. Goldthwaite, whose contribution to the interpretation of the glacial phenomena is important; and Dr. G. O. Smith, who has described the economic aspects of the gold deposits.

It is hoped that this paper will contribute to the further understanding of the geology of the eastern Green Mountain belt and form a suggestion for future work in determining the stratigraphy and structure of the early Paleozoic rocks of that region.

GENERAL SUMMARY OF GEOLOGY

The Plymouth-Bridgewater area is a maturely dissected upland with a relief of about one thousand feet. Features indicating two cycles of erosion are present; mature pre-glacial upland and open valleys, and youthful post-glacial tributary valleys.

The principal rocks are the members of a series of metamorphosed sediments ranging in age from Ordovician through probable Cambrian to Pre-Cambrian. Lithologically, the formations are at present: quartzites with various impurities, phyllite, dolomite, quartz-mica-chlorite schist, and many other varieties of schist present in minor quantities. The various rock types outcrop in parallel bands oriented approximately north and south the youngest on the east and successively older bands in order westward.

The metamorphosed sediments are intruded by igneous rocks of at least four different ages and types. In the Pre-Cambrian sediments a granite gneiss is the most common intrusive, although mafic rocks are also present. Intruding the younger sediments, metamorphosed mafic dikes and diorite are the most common. Two types of unmetamorphosed igneous rock are found in the area, a granite of very limited distribution, and many small dikes of diabase and camptonite in widely scattered outcrops. Vein quartz and, more rarely, associated pegmatite is very common throughout the Paleozoic section in the form of small veins and irregular lenses.

Glacial till and glaciofluvial deposits cover much of the country and are of particular hindrance to geological field work in the southwestern part of Plymouth.

The major structure is a homocline, in which the strata strike within a few degrees of north and dip east at angles usually greater than forty degrees. The major structure is complicated, however, by considerable, superimposed, small scale isoclinal folding.

In most of the Cambrian series the bedding and schistosity are parallel, as determined at the contact of beds of unlike lithology. In the Ordovician and uppermost Cambrian a second, partially developed, schistosity which dips north at a low angle, is developed in addition to the schistosity parallel to the bedding, which here dips at very high angles east or west.

PHYSIOGRAPHY

The towns of Bridgewater and Plymouth are situated within the Green Mountain division of the New England Highlands and are characterized by considerable irregularity of surface. The entire region has been reduced to slope, and flat areas are found only on terraces in a few of the larger valleys. On the other hand, the relief is not great, but is about one thousand feet as an average. The elevations above sea level range from 820 feet at Bridgewater on the Ottauquechee River, to 3,278 feet at the crest of Salt Ash Mountain in southwestern Plymouth. Many of the

hills are 2,000 feet above sea level and a few exceed 2,500, but there is no *marked* accordance of summit levels.

The stage of erosion of the stream valleys ranges from extreme youth to adolescence. Most of the streams are turbulent mountain brooks, occasionally showing in their valley profile the

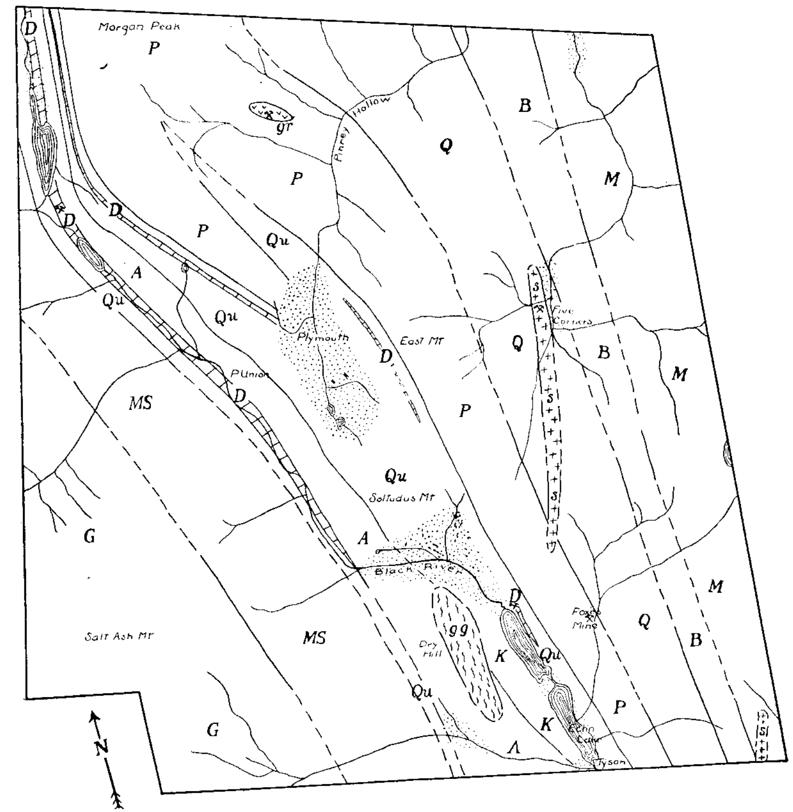

FIGURE 2.—Geological Map of Plymouth, Vt.—1 inch = 1.75 miles.

M—Missisquoi Group, B—Bethel Schist, Q—Ottauquechee Group, P—Pinney Hollow Schist, Qu—Quartzites, K—Conglomerate, D—Dolomite, A—Albitic Schist, MS—Mendon Series, G—Mt. Holly Series and Gneiss, s—Steatite, gr—Granite, gg—Granite Gneiss of Dry Hill, Stippling—Glaciofluvial Deposits.

effects of two cycles of erosion; an older cycle which had reached a submature stage before the start of the present one, which has resulted in the incision of sharp gorges in the older valleys. The larger streams such as the Ottauquechee and lower Black Rivers, have reached a subgraded condition, although the gradients are as yet too high for mature streams, and there is little tendency indicated toward a widening of the valleys by lateral erosion. Much of the drainage of the large streams is affected by the presence of glacial deposits in the valleys, and lakes are occasionally formed. The influence of glaciation on topography will be considered more at length below.

The region, like many of the streams, shows the effects of two cycles of erosion. An older pre-glacial cycle, in which the major features of the present topography were developed, has produced the mature outlines of the upland and a younger, post-glacial cycle has been superimposed upon this, deepening the stream valleys, but has had but little success in dissecting the older mature surface. No accordance of summit levels is apparent and during the time of formation of the Cretaceous peneplain in nearby regions to the east, this area was probably covered with low hills flanking the higher Monadnock ridge of the Green Mountains to the westward. The oldest cycle of erosion probably started in the Tertiary and was interrupted by the Quaternary glaciation, to be followed by the present cycle which has advanced to early youth.

The lithology and structure of the formations has, in some instances, exerted a marked control over erosion. This is particularly noticeable in the case of the dolomite beds of Plymouth. These strata outcrop with a general north-south trend and, since they are readily dissolved and eroded, strike valleys have been formed along the major beds. The upper Black River Valley constitutes the best example of such erosional control. A bed of white or pink dolomite outcrops along the bottom of the valley from its head southward to a point about two miles south of Plymouth Union. At the place where the dolomite bed ends, the valley swings abruptly to the east across the strike of the overlying schists until another, stratigraphically higher, dolomitic zone is reached at the head of Amherst Lake and then follows this zone southward along the strike, into Ludlow. The trough-shaped depression extending from Plymouth Pond on the north, past Grass Pond to Plymouth Village on the south, is likewise formed along a dolomite zone.

Just as the dolomites tend to cause valleys, some of the more resistant schists and quartzites tend to form ridges or lines of hills. The very pronounced range of hills extending north from Bridgewater Village follows just east of the line of contact of the Ordovician phyllite and the Pre-Ordovician schists (see map) and is undoubtedly influenced by the resistance of the phyllite to erosion. To a lesser extent, the Bethel and Pinney Hollow Schists, very similar in lithology, have favored the formation of hills. Many of these hills have a gentle eastward slope due to the eastward dip of the bedding and an abrupt westward declivity, brought about by the control exercised by a persistent system of joints parallel with the strike and at right angles to the easterly dip of the schistosity. This same feature of gentle eastward and steep westward slope is illustrated along the east side of the Black River Valley in the older Cambrian rocks. Occasionally well defined dip slopes have been formed, as on the quartzites east of Tyson, or on the quartzite conglomerate north of Tyson in southern Plymouth.

The type of topography which is so characteristic of the nearby town of Woodstock, namely broad, open valleys and rolling, soil-covered hills with very few outcrops, is found in this area only in northeastern Bridgewater, where the belt of outcrop of the Waits River Limestone extends across the corner of the town. This limestone, although siliceous and often interbedded with phyllite, disintegrates readily by weathering and tends to form moderate slopes, thus giving rise to a much less precipitous country than the gneisses and schists to the westward.

The igneous intrusions of Plymouth and Bridgewater exert but little control on the topography. In general the metamorphosed intrusives, such as the amphibolites and steatites, produce effects similar to the surrounding schists. The lamphrophyric dikes, on the other hand, are considerably jointed and break up readily into separate blocks which are removed by erosion so that long trench-like depressions often result. These dikes are neither large nor numerous, so that this erosional phenomena is unimportant in the area as a whole.

Interest in the effects of glaciation on this region was evinced as early as the middle of the last century and is stressed in Edward Hitchcock's report on the geology of Vermont.[1] He advanced the theory that *local* glaciers had once occupied the valleys of the Ottauquechee and Black Rivers, rising in the hills and flowing east or southeast. Hitchcock did not, however, attribute the distribution of ordinary drift to strictly glacial action, but advocated the theory then prevalent, that floatinig icebergs were responsible for the scattering of drift material and the grooving of striae on the exposed rocks of the hills, reserving the term glacial to apply only to the work of local, mountain glaciers. As late as 1908, C. H. Hitchcock[2] has advocated the former presence of valley glaciers in the Ottauquechee district, but Goldthwaite[3] presents a clear case to the contrary and his observations are readily confirmable in the field. No cirques are present to serve as gathering grounds for snow and the phenomena such as heaps of glacial-borne material in the valleys, cited by the Hitchcocks as terminal moraines of valley glaciers, have been

[1] Hitchcock, E., Sr., Geology of Vermont, Vol. I, 1861, pp. 85-86.
[2] Hitchcock, C. H., Rpt. Vermont State Geologist, Vol. VI, 1907-08, p. 180.
[3] Goldthwaite, J. W., Rpt. Vermont State Geologist, Vol. X, 1915-16, pp. 42-73.

found to be kames of glaciofluvial origin and were probably formed by the water from local tongues of ice extending from the margin of the retreating continental ice sheet. It is evident that all the glacial phenomena of the district are to be attributed to continental glaciation; the chief effects of which are the kames and terraces in the valleys and unsorted drift and smoothed, striated rock ledges on the hills.

Kames are particularly common near West Bridgewater, in the vicinity of Plymouth Village, the head of Amherst Lake, and near Tyson in southern Plymouth. A typical isolated kame is that between Amherst and Echo Lakes. This has been cut into for road material and shows distinct stratification and sorting of the constituent sand and gravel. The deposition of kame material has been responsible for the formation of most of the ponds and lakes of the district. The deposits at the head of the "Old Notch" near Plymouth Village have, as Goldthwaite has pointed out, obstructed the course of the glacial (and pre-glacial?) stream which carved this notch and have diverted the drainage from the Black River to the Ottauquechee, after the melting of the ice had freed the outlet through Pinney Hollow to the northeast.

Terraces of glaciofluvial origin are common in the major stream valleys, particularly along the North Branch of the Ottauquechee and in nothern Hale Hollow and Pinney Hollow, and lake terraces are evident on the east shore of Echo Lake. The stream valley terraces are found only near the valley bottoms and vary in height from about five to twenty-five feet. As many as six small terraces totaling no more than fifty feet may be present, as at Bridgewater Corners where the North Branch joins the main Ottauquechee. The terraces do not persist at any one level, but vary locally, hence are considered to be the result of deposition by rivers. They are most commonly found where tributary streams enter larger ones and may thus be in part, delta deposits. The terrace at Tyson, where Patch Brook enters the Black River, is an illustration. The well-preserved terrace on Echo Lake near the mouth of Kingdom Brook is very probably a delta deposit formed by the brook entering the lake when the level of the latter was about thirty feet higher than at present. A narrow lake terrace which is persistent at this same level on the eastern side of the lake was probably formed along the shore at that same time.

Glacial till made up of compact clay with imbedded pebbles and boulders is occasionally present on hillsides, particularly on those with northern exposure, and is revealed on the banks of the smallest brooks. The best example of such deposits was noted on the northwest side of Dry Hill in southern Plymouth. The till contributes to the filling in of irregularities in the underlying

rocky floor and hence aids in the smoothing out of the surface contours.

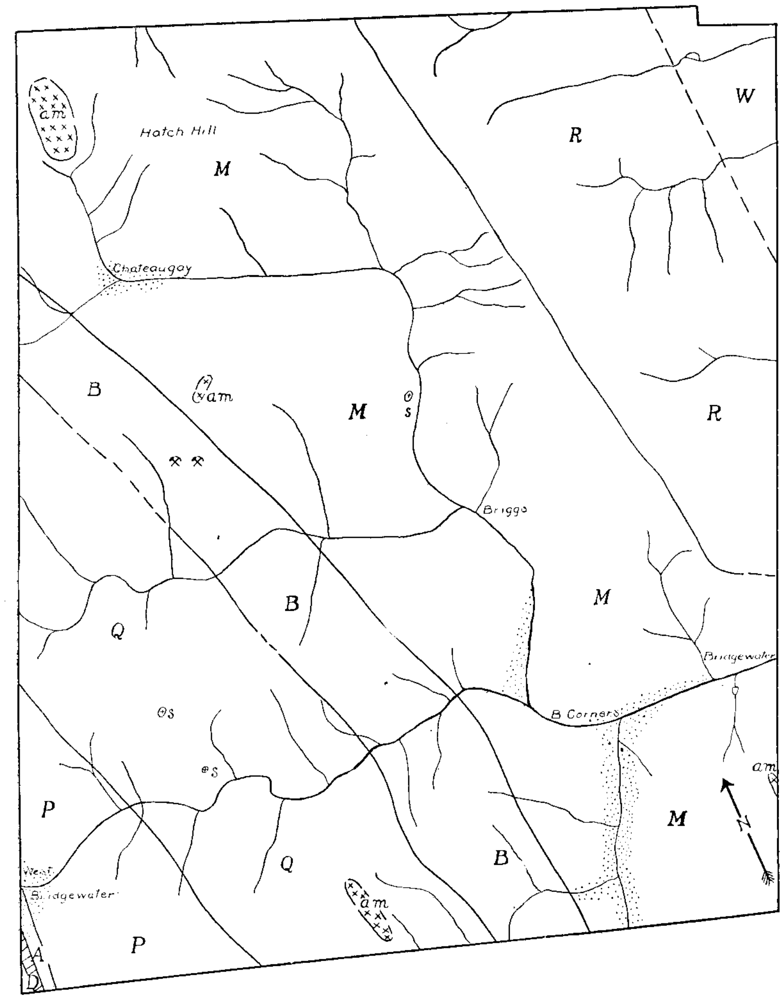

FIGURE 3.—Geological Map of Bridgewater, Vt.—1 inch = 1.6 miles. W—Waits River Limestone, R—Randolph Phyllite, M—Missisquoi Group, B—Bethel Schist, Q—Ottauquechee Group. P—Pinney Hollow Schist, A—Albite Schist, D—Dolomite, am—Amphibolite, s—Steatite, Stippling—Glaciofluvial Deposits.

The erosional effects of glaciation are most apparent on the bare ledges, both in the valleys and on the hills. Most of the outcrops are distinctly rounded and bear striæ oriented in a northerly direction, although they are somewhat variable, particularly at low elevations. A second type of erosional feature, due secondarily to glaciation, is the abandoned stream channel between Plymouth Pond and Black Lake in northwestern Plymouth. This channel has the form of a gorge about twenty feet deep, known locally as "The Narrows," and was formed chiefly in a bed of dolomite, although it is also cut in the quartzites on either side. In the latter, several large pot holes and chutes are well preserved; the best of these a few yards south of the head of Plymouth Pond, are of considerable size, ten or more feet across, and could not have been formed by any stream now present in the vicinity. This channel is clearly a result of glaciofluvial erosion and must have been formed when the valley to the north was blocked, probably by a local ice tongue, and the drainage from that district into the Ottauquechee was diverted southward into the present Black River valley. The erosion channels known locally as the "old" and "new" notches near Plymouth Village, and which have been mentioned above, are similar abandoned stream beds of glaciofluvial origin.

DESCRIPTIVE GEOLOGY

PRE-CAMBRIAN

Very little progress can be made in classifying the Pre-Cambrian rocks of Plymouth because of the pronounced lack of connected outcrops. It is evident, however, that a broad subdivision into two parts is possible; an eastern belt of highly metamorphosed sediments and a western area in which metamorphosed igneous rocks associated with occasional sediments of an older series are predominant. The eastern group is probably the Mendon Series,[1] the younger Pre-Cambrian of the Green Mountain region, while the western group includes the Mount Holly Series, or older group of Pre-Cambrian sediments, intruded by igneous rocks. The type locality of the latter series is in the town of Mount Holly, adjoining Plymouth on the southwest. The Mendon Series takes its name from the town of Mendon where it is best exposed on the western side of the Green Mountains, about ten miles northwest of Plymouth.

Both of these series of rocks were considered by Whittle to be of Algonkian age, but the term Algonkian was not used at that time (1894) in the same sense as it is employed at present. The Algonkian System was originally defined in 1889 as including all Pre-Cambrian *clastic* rocks[2] and would thus include part of the present Archean as well as portions of the present Algonkian. In view of more recent research and nomenclature it is

[1] Whittle, C. L., Jour. Geol., Vol. II, 1894, pp. 396-429.
[2] Wilmarth, M. Grace, U. S. G. S. Bull. 769, 1925, p. 103.

more probable that the Mount Holly Series is Archean in age, and possibly Grenville, although no convincing proof can be offered in support of the latter thesis at the present time. The apparent complexity of structure, the degree of metamorphism, and the presence of numerous areas of carbonate rocks are all strongly suggestive of a close relationship between the Mount Holly Series and the Grenville Series of eastern New York State.

The Mendon Series is particularly well exposed in a few tributaries on the west side of Black River but the Mount Holly Series is largely covered by high level swamp and till deposits so that outcrops are small and often widely scattered except on occasional, steeply sloping hillsides. The best exposures of the latter series are on the southeast slopes of Salt Ash Mountain, and Proctor Hill nearby.

THE MOUNT HOLLY SERIES

Three distinct types of metamorphosed sediments were recognized in the Mount Holly Series in Plymouth, but no effort was made to separate the different types in mapping. Dolomite found on the north side of Proctor Hill on the Plymouth-Shrewsbury line, is the most unquestionable sediment. The rock is light grey both on the fresh and weathered surfaces and shows little effect of weathering other than solution of the carbonate minerals. The dolomite is fine grained and completely re-crystallized. Small veinlets of clear colorless quartz are occasionally present, and in the vicinity of these the carbonate is as coarse as one millimeter in grain and has been partially changed to calcite. The relation of the dolomite to the other formations is indeterminate at this locality because of surrounding glacial drift. Similarity between this dolomite and those of the Cambrian series to the east is not marked, although in size of grain and color it does resemble the youngest of the Cambrian dolomites, just beneath the Pinney Hollow Schist.

Several localities at which "limestone" occurs, are mentioned by Whittle[1] in his description of the Mount Holly Series of the adjoining type region.

> "A section on the southwest slope of Ludlow Mountain, . . ., exhibits at least two beds of coarse limestone grading into tremolite and green hornblende, interstratified with layers of schist. On the southwest slope of Salt Ash Mountain a bed of tremolite limestone interstratified in biotitic gneiss trends northwest. At Northham village, a similar coarse limestone occurs associated with a vitreous quartzite, a laminated eruptive rock and a rusty muscovitic schist. All through the core there are patches of these coarse limestones in a great variety of association, such as with coarse augen-gneisses (a common occurrence), quartzites, schists, and other rocks. Fine-grained blue marbles are present in two or three localities. In all cases the limestones are in irregular lenses, and are extremely local; their occur-

[1] Whittle, C. L., Jour. Geol., Vol. II, 1894, p. 415.

rence with coarse gneiss affords no evidence of structure; these scattered irregular outcroppings and differences of association make them impossible of correlation. There may be two horizons of limestone in the core or there may be a dozen. The same is true of the quartzites and other sedimentary rocks."

Dale,[1] more recently, has described several occurrences of dolomite in the lower Pre-Cambrian rocks of the towns to the south and west of Plymouth. His observations agree in the main with those of Whittle, particularly in regard to the association of schists and gneisses with the dolomites.

White quartzites are often present in the glacial drift of southwestern Plymouth as subangular blocks, and have probably been derived from strata of quartzite in the Mount Holly Series, particularly from the east side of Salt Ash Mountain and possibly from other localities now under cover. These quartzites differ from those of the younger rocks in that they are more vitreous and less granular. Outcrops of the quartzites are rare, in Plymouth, and do not clarify the question of their relationship to the other rocks of the series. Coarsely banded schistose quartzites, containing biotite, are present in the injection gneiss of Salt Ash Mountain on the southeast side, near the crest. These probably represent impure, possibly shaly, sandstones especially since they are associated with considerable thickness of chlorite schist, which were most probably shales before metamorphism.

In addition to the dolomite and quartzite, a third type of rock which may be a metamorphosed sediment is found in the lower Pre-Cambrian of Plymouth. This rock is a chlorite-sericite-quartz schist, predominantly chloritic, injected by layers of younger granitic material *lit par lit*. This type of rock is exposed over a vertical range of more than one thousand feet on the south slope of Salt Ash Mountain and is by far the most common rock type in the older Pre-Cambrian of the district. The layers of altered granite range in thickness from microscopic laminæ up to irregular sheets more than a foot in thickness.

The schist is uniformly dark green and fine textured with well-defined parting produced by the parallel orientation of plates of chlorite. Small flakes of biotite are occasionally present and fine granular quartz is consistently present as scattered grains in the chlorite. The mineral composition and structure of the schist over a considerable area are considered as indicative of a probable sedimentary origin.

The igneous material intrusive into the chlorite schist is clearly granitic in composition. Orthoclase is the most prominent mineral and occurs as distinct crystals, often rounded, and of a size proportional to the thickness of each individual layer of granite. Abundant layers about one-half inch in thickness

[1] Dale, T. N., U. S. G. S. Bull. 589, pp. 20-22.

contain feldspars about one-eighth inch in diameter, and layers six inches or more in thickness contain feldspars three or four inches across. Finely granular quartz encloses the feldspar and the structure of the whole, indicates considerable shearing. Most of the granitic layers alternately swell and pinch along the strike, so as to produce a series of lens-shaped masses. Sericite and chlorite are accessory minerals, but are present only in small quantities. The color of the rock is characteristically a dull white with but few dark minerals.

In addition to the igneous rock of the injection gneiss described above, two other distinct types of metamorphosed intrusives were noted in the district. A massive granite gneiss is well exposed on the north slope of Proctor Hill, in the southwest corner of Plymouth, in large, well-rounded ledges. The rock is predominantly white or light pink with narrow bands of green chlorite. The important minerals are quartz and feldspar, the former slightly in excess of the latter. Both minerals occur as irregular interlocking anhedral grains of even distribution and 0.5 mm. or less in size. The feldspar is mostly orthoclase, but a minor amount of albite showing coarse twinning and a higher index of refraction, is also present. The presence of a few narrow veinlets of clear quartz grains is interpreted as indicating movement, probably shearing, across the panes of schistosity and later healing of the fractures by the crystallization of second generation quartz. Muscovite is common, roughly segregated in bands made up of bundles of coarse laths, often associated with large irregular flakes of chlorite. Epidote is abundant as grains 0.3 mm. or less in cross-section and often columnar, cutting the four minerals mentioned above. Many crystals of feldspar, and the earlier quartz, are clouded with minute epidote grains. Apatite, diotite, chlorite and hematite are accessory minerals, the latter causing the pink color of the rock.

The composition and structure of the gneiss are interpreted as indicating an original biotite-muscovite granite in which recrystalization has occurred, with the formation of epidote and chlorite at the expense of the original feldspar and biotite or other mafic minerals, respectively. Similar gneisses are very common in the glacial drift of the vicinity.

On Great Roaring Brook near the Shrewsbury line, 1.2 miles west of Plymouth Union, a small area of metamorphosed basic igneous rock is exposed, underlying the Mendon Series. The principal rock type is an epidiorite with slightly schistose structure and composed of approximately equal proportions of hornblende, and feldspar and quartz. This gneiss is overlain by, and encloses, irregular areas of a massive moss-green rock apparently an altered phase of the diorite. This rock is composed almost entirely of chlorite enclosing small patches of calcite. The composition and relation of the chloritic rock to the diorite suggest that the former represents either a metamorphosed contact phase of the latter, or a weathered zone formed prior to the deposition of the overlying Mendon Series and since metamorphosed. The diorite is intruded by veinlets of both granular quartz and pegmatite.

MENDON SERIES

The Mendon Series in Plymouth consists in general of micaceous quartzites, quartz-muscovite chlorite schists and some coarse limestone containing abundant micaceous minerals. The various lithological types each show complete recrystallization of the major constituents and retain but few of the original sedimentary characters. All members of the group which were studied are, however, considered to be former sediments because of their individual mineral compositions and distinctly stratified arrangement. The belt of outcrop of the series is about a mile wide, bordering the Mount Holly Series on the east. Structurally, the Mendon Series is less complex than the older Mount Holly Series, but small close folds, overturned from east to west are common in some of the less massive members. It is probable that larger isoclines are also present in which overturning of the beds has produced the present dip of about twenty-five degrees east, but conclusive evidence of such folds is not present in the Plymouth area.

Three excellent sections are exposed across the strike of the formation along Tinker Brook, Great Roaring Brook and Little Roaring Brook, but the intervening areas exhibit only scattered outcrops of obscure relationships. The three sections, although similar in the general character of the rocks exposed, differ in detailed appearance and order of succession of rock types.

The Roaring Brook section, west of Plymouth Union, is considered to be the best local exposure of the Mendon Series, because the section is nearly complete from a gneiss at the base to the Cambrian dolomite at the top. The rocks outcrop in the bed of the brook and along the valley sides for a distance of slightly less than a mile and the elevation drops from 1,830 at the lower contact to 1,300 at the contact with the Cambrian. The total *apparent* thickness of the section is about 2,200 feet, but this is undoubtedly greater than the actual thickness because of close folding and minor overthrusting of which there is considerable evidence.

All the rocks of the Roaring Brook section are distinctly schistose and are consistently made up of the four minerals, quartz, chlorite, muscovite and magnetite, as essential constituents. These minerals are usually very well crystallized, much more so

than in the case of the minerals in the rocks which overlie the Mendon Series. Accessory minerals which are recognizable in a microscopic examination are calcite, pyrite and feldspar. Quartz is by far the most abundant mineral. The rock types vary between two extremes and are found in all gradations between a chloritic mica schist and a micaceous, chloritic quartzite, although the latter is the most abundant type. The absence of strongly contrasting or unique beds in the section renders impossible the establishing of a datum plane for solving the structures and stratigraphic sequence of the beds. In general, the lower part of the formation is here made up mostly of fine-textured pale green chlorite-mica schists, the middle part of coarser, light colored, highly quartzose schists and the upper part of dark green, somewhat granular quartz-chlorite schist intermediate between the other two in composition.

A microscopic examination of the more quartzose phase of the formation shows the following minerals: *quartz,* abundant as anhedral grains up to 0.5 mm. in diameter evenly distributed through the rock, and with inclusions of chlorite, mica, rutile and zircon; *chlorite,* abundant as irregular patches, usually with parallel elongation, well crystallized, in size up to 1.0 mm. in length; *muscovite,* common as well defined laths surrounded by quartz; *calcite,* common as small irregular interstitial grains; *zircon,* a few oval grains not more than 0.1 mm. in size, probably original clasic grains; *rutile,* common as groups of tiny, dark brown needles in the quartz; *apatite,* occasional subhedral shattered grains; *epidote,* in occasional irregular grains, slightly shattered and altered; and *feldspar* of somewhat doubtful composition, probably albite ($Ab_{90}\,An_{10}$) as determined from a few, simply twinned, anhedral crystals.

The Tinker Brook section in northern Plymouth, about a mile north of Great Roaring Brook, is essentially the same as the section described above, with but one notable exception. A new group of closely associated rocks, outcrops at an elevation of 1,600 feet beside the brook. They consist of a white, slightly micaceous quartzite overlain by limestone interbedded with chloritic schist. The quartzite shows zones of shearing and the limestone is strongly contorted, often showing flowage, where etched by weathering, and is drawn out into small lens-shaped masses enclosed by schist. The limestone has a rough distribution in layers a few feet thick, striking north and dipping twenty degrees east, and interbedded with quartzites or schist. The other rocks of the section above and below the quartzite-limestone horizon bear a marked resemblance to those of Great Roaring Brook, although there is more feldspar in most of them and the quartz, although granulated, often preserves outlines suggesting rounded sand grains.

In southern Plymouth the best section through the Mendon Series is exposed on Little Roaring Brook, east of the crest of Salt Ash Mountain. The series of outcrops is, however, not as complete as in the two northern sections. The lowermost formation here exposed is a white, sugary quartzite with grains of bluish quartz about 1.0 mm. in diameter, scattered through it. A small amount of biotite and sericite is developed as small flakes. The formations overlying the quartzite are similar to those of the other sections, dark, highly quartzose, mica-chlorite schists with considerable accessory calcite and some biotite.

Outcrops of the Mendon Series near the southern border of Plymouth are scarce, but the exposures on Patch Brook and the crest of Tinney Hill, west of Tyson, are enough to show the similarity of the rocks there to those farther north.

The Mendon Series is considered by the writer to represent a group of metamorphosed shales, limestones and sandstones, with many intermediate mixed varieties among these three simple types.

AGE OF THE POST-CAMBRIAN FORMATIONS

The rocks which overly the Pre-Cambrian formations are divisible into two main groups; a series of quartzites, dolomite and various schists, overlain by a second group made up of a limestone and associated phyllite. The latter group is of known Ordovician age, as determined by fossils in areas to the north along the strike, but the former is of indefinite age. It seems advisable to refer this series provisionally to the Cambrian, for three reasons: 1. The approximate extension of this series to the north into Canada is referred to the Cambrian by the Canadian Geological Survey (on meager paleontological evidence); 2. the position of this thick series between Ordovician and probable Pre-Cambrian rocks with unconformities separating it from each, infers a Cambrian age; 3. a considerable thickness of Cambrian sediments of proven age is present on the western side of the Green Mountains only a few miles away and it seems reasonable in view of the fact that the sediments on both sides of the axis were very evidently similar in lithology before metamorphism, that sedimentation went on simultaneously on both sides of the axis during the Cambrian and that the series in the area under discussion is the counterpart of the known Cambrian to the west. Thus although a Cambrian age can not be proved for this group on direct paleontological evidence, it will be described as of that age by the writer.

OLDER CAMBRIAN GROUP

Outcropping in a belt to the east of and overlying the Mendon Series is a group of related formations, several with very distinctive lithology, but of such limited persistence along the strike that it is considered impractical at present to suggest separate formation names for the different lithologic units. The group is overlain and limited on the east by the Pinney Hollow Schist, which has an appearance sharply in contrast with that of the older rocks. The contact between the two is comparatively sharp, *i.e.*, the contact can be located within ten feet at several places.

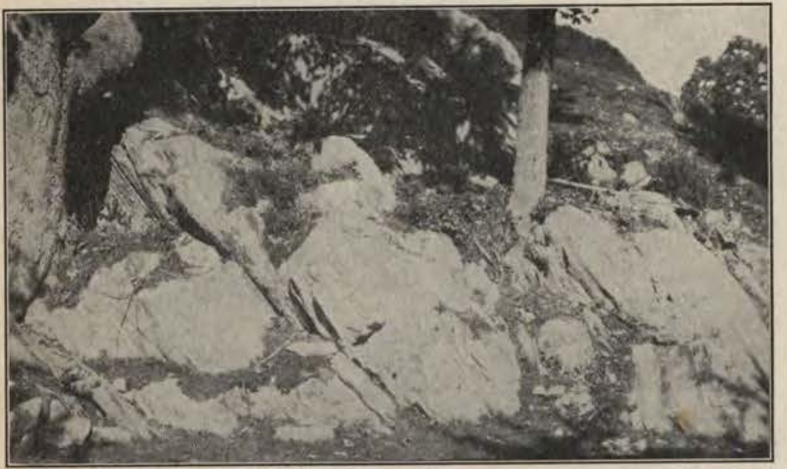

FIGURE 4.—Basal Quartzite, Cambrian, showing easterly dip, East Bridgewater.

The chief rock types of the older Cambrian group are: quartzite of several varieties, conglomerate, dolomite, and a dark, mica schist containing many small phenocrysts of albite. The group is most conveniently described by tracing the changes in lithology which take place in each unit of the section from north to south along the strike. The best, most continuous outcrops are those at the west base of Morgan Peak in northern Plymouth and in the vicinity of Solitudus Mountain in the center of the town.

LOWER QUARTZITE AND DOLOMITE

The basal beds of the main sequence consist of a variable group of rocks, chiefly dolomite and white quartzite, two hundred feet or less in thickness. This group is best exposed in northwestern Plymouth at the Bridgewater line and at the "Narrows" at the head of Plymouth Pond. Individual layers vary considerably along the strike although the lithology of the group as a whole is constant. The lowest beds are quartzite, either white or light grey, and containing occasional dolomitic and pebbly layers. The major thickness of the quartzite is attained in the northwest corner of Plymouth and decreases from about one hundred feet in that district to one quarter that thickness in southern Plymouth. The rock is distinctly granulated and has cataclastic structure, although pebbles of bluish granulated quartz have undergone very little distortion during the movement producing this structure.

The basal quartzite member grades upward into a persistent horizon of dolomite, which in northern Plymouth is about forty to fifty feet thick. This thickness, like that of the underlying quartzite, decreases to the south and is less than five feet at a point two miles south of Plymouth Union, where it disappears beneath glacial drift. The dolomite is situated in or near the bottom of the Plymouth Valley throughout its length and was probably the controlling factor in the formation of the latter. Although sometimes siliceous and nearly a quartzite in composition, the dolomite is largely pure and is either white or light pink. The rock is completely recrystallized, but is of very fine grain. The pink color is referred by Dale[1] to the presence of manganese and iron in small amount. Most of the lime production of the district was derived from this main bed of dolomite, north of Plymouth Union.

The strata overlying the dolomite are white and sandy, with some patches of dolomite and often with large subhedral orthoclase crystals, up to eight millimeters in cross-section. Much of the orthoclase is pink and has tiny inclusions of hematite and chlorite oriented parallel to the principal cleavage direction. Many of the grains are well rounded and appear to be clastic derivatives of the feldspar from a coarse granite. Grains of quartz of a size comparable with the feldspar are occasionally present, but most of the quartz is completely recrystallized to a very fine grain in which the outlines of the larger primary clasts are still visible. Much of the orthoclase is also fractured so that the whole rock has a cataclastic structure in which the quartz is much more granular than the feldspar.

ALBITIC MICA SCHIST

In a persistent bed outcropping above the quartzite-dolomite group, is an unusual variety of black, porphyritic mica schist. This constitutes a distinct, continuous formation about nine hundred feet thick extending along the steep westward-sloping hillside on the east side of the Black River Valley, from northern Plymouth as far south as the curve of the river at Soltudus Mountain. South of there the formation is largely under cover of glacial drift, but seems to thicken considerably in the Patch Brook valley, although this may in part be due to the intrusion of granite (gneiss) on the east crest of Dry Hill within the belt of outcrop of the schist.

[1] Dale, T. N., U. S. G. S. Bull. 589, 1915, p. 27.

The rock is distinctly schistose and is characterized by a porphyritic texture, but with the phenocrysts (metacrysts) not more than 3.0 mm. in cross-section. The formation is quite uniform in lithology along the entire belt of outcrop. The color of the ground mass of the rock is uniformly dark grey or black, in contrast with the small metacrysts of colorless or white albite and quartz. The essential minerals are: Quartz, as small, angular, anhedral grains about 0.2 mm. in size and often segregated in groups; muscovite, common as bundles of fibers with parallel orientation; chlorite, abundant as blades and patches, often with inclusions of accessory minerals; and plagioclase, albite to oligoclase, as simple twinned or untwinned crystals with many inclusions of the other minerals. The accessory minerals are: Tourmaline, as blunt prisms 0.3 mm. or less in length, some of which may be rounded primary clastic grains; zircon, as occasional well-rounded grains, in one instance with a surrounding pleochroic halo in chlorite; magnetite (and ilmenite?) common as small irregular patches and dots scattered rather evenly through the schist; and biotite, as scattered groups of blades, largely altered to chlorite and magnetite and scarcely recognizable.

The rock resembles a mica schist derived from the metamorphism of a shale except in one regard, the presence of the abundant albite representing a proportion of sodium abnormal in an ordinary sediment. As judged from its appearance in thin sections the albite is undoubtedly secondary. It is furthermore not confined to the albitic schist in its distribution, but is also common in the overlying quartzite and conglomerate often as large well-defined euhedral crystals. Upon this fact is based the conclusion that the materials necessary for the formation of the albite were introduced during, or after, the principal metamorphism of the original sediments. The original form of the present albitic schist is considered, by the writer, to be a black shale. Evidence to uphold this view was discovered in the formations overlying the schist. Angular fragments and tiny lenses of shale were found enclosed in the quartzite and dolomite above, in which they had been protected from the considerable stresses to which the less competent underlying shale reacted.

MIDDLE QUARTZITE, CONGLOMERATE AND DOLOMITE

Above the albite schist and extending from Morgan Peak on the north to Solitudus Mountain on the south, is a series of massive quartzites in beds from three to six feet thick and with very uniform dip of about forty-five degrees east. The thickness of this formation is in doubt in the Morgan Peak section but reaches a maximum of slightly over seven hundred feet in the vicinity of Plymouth Notch. The best exposures are on the east slopes of the hills on either side of the "Notch," where the characteristic habit of outcrop of this quartzite is well shown. The rock is very resistant to decomposition, but a persistent system

FIGURE 5.—Metamorphosed Conglomerate, Tyson.

of joints at right angles to the bedding and parallel with the strike of the formation, so directs erosion as to produce a series of small cuestas and vales with a general north and south trend and spaced a few yards apart east and west. The vales between the cuesta ridges are usually from three to fifteen feet deep and partially filled with mud or water.

The typical rock is dense, but distinctly granular and not vitreous. Some of the beds are very feldspathic, containing feldspar of composition ranging from albite to oligoclase, in addition to the granular quartz and occasional blades of muscovite. The feldspar is secondary and is of a composition rarely found in arkose. Its origin was discussed in the description of the preceding formation.

The massive quartzites extend as far as the Black River valley south of Solitudus Mountain where they disappear beneath the

glaciofluvial deposits in the valley. In the line of strike of the formation south of the river, however, is a quartz conglomerate which is a very probable equivalent of the quartzite farther north, although the river valley effectively bars any chance of tracing one into the other to prove this theory. The conglomerate is best exposed in a section due west of the kame between Amherst and Echo Lakes. The arêa of outcrop extends from the west shores of the above lakes, westward nearly to the crest of Dry Hill and from the head of Amherst Lake on the north nearly to the foot of Echo Lake on the south.

The conglomerate is composed of stretched pebbles of quartzite and granite gneiss in a schistose matrix composed of fine granular quartz and muscovite with accessory magnetite, zircon, tourmaline and secondary albite. The pebbles, or phenoclasts, vary in size from less than one-fourth inch in the finer phases of the formation to some eighteen by thirty-six inches in the coarsest phase near the base. The phenoclasts are greatly elongated in the plane of the bedding, which is oriented slightly west of north and dips east forty to fifty degrees. In cross-sections cut parallel to the strike and perpendicular to the bedding, the pebbles are lens shaped with the greatest dimension in the plane of the bedding and lesser dimension at right angles to it. The effect produced is as if the original pebbles were flattened from above and stretched from east to west. The gneiss pebbles were flattened and drawn out much more than those composed of quartzite. Sharply defined, rectangular, euhedral crystals of secondary albite are common in the micaceous matrix, and range in size from occasional ones one-half inch across to microscopic ones. Tiny octahedrons of magnetite are also present locally in the matrix.

The coarseness of the conglomerate decreases north, south and east from a spot at the base of the formation west of the foot of Amherst Lake. The prominent outcrops on the west shore of the latter lake, about midway of its length are composed of some of the upper beds which have but few pebbles and are like the matrix of the coarser phases. A rock closely resembling this upper phase is found north of the road leading west from the head of Amherst Lake and probably represents the northward extension of the normal conglomerate of Dry Hill but the area between is largely covered by a dense growth of underbrush and blackberry bushes so that a direct connection cannot be traced under present conditions. In the direction of Tyson the normal conglomerate becomes less coarse in texture and is finally replaced by a dark grey, graphitic, mica schist, exposed in the hillside pasture a few yards northwest of the foot of Echo Lake.

A lens-shaped mass of pure white dolomite is present in the conglomerate on Dry Hill three hundred feet above, and a few hundred feet west of, the head of Echo Lake. The dolomite body is largely under cover, but is at least two hundred feet long, north and south, and fifteen feet thick near the middle of the outcrop, where a small quarry was opened and rock extracted for "burning" in a kiln a few yards away. The rock is very similar to that in the large bed to the north of Plymouth Notch. The shape of the body is probably due in part to squeezing during metamorphism as well as to the original shape of the mass of sediment, for the lens is oriented in the same position as the stretched pebbles in the surrounding conglomerate. The association of dolomite and conglomerate or coarse, pebbly quartzite is evident in all the important beds of dolomite in Plymouth and is believed to be unusual in that the conditions of sedimentation of the two rock types are usually considered to be dissimilar.

A second lens, evidently aligned with the above, is mapped by Dale[1] near the head of Amherst Lake in the northern part of the conglomerate area, but this was not found by the writer.

To return to the Mount Morgan section, the stratum overlying the massive quartzite is a bed of dark grey, carbonaceous dolomite, less than a yard in thickness. The dark rock is cut by narrow irregular bands and blotches of white dolomite apparently representing former fractures healed by the recrystallization of secondary dolomite in the seams. The dolomite horizon persists southward from the 1650 feet level on the Bridgewater-Plymouth line on Morgan Peak to a point three hundred and fifty yards east of Plymouth Lake, midway of the lake from north to south. The line of outcrop of the bed then turns slightly eastward up into a shallow valley and at the same time the bed thickens and changes in character to a pure white dolomite which outcrops in a widening belt past Grass Pond as far as Plymouth Notch where the kame deposits cover the formation. Several quarrys were formerly operated in the white dolomite and a considerable quantity of rock extracted for roasting in nearby kilns.

The section below the upper quartzites on East Mountain is practically all covered by glacial deposits. Three beds of dolomite are exposed beside the road east from Moore's Ponds, south of Plymouth Village. Rock from the upper beds was quarried and roasted in nearby kilns, but the lower one is intruded by vein quartz to such an extent as to render it worthless. The relation of these dolomite beds to the other formations in the vicinity is completely obscured by surrounding cover, but they seem most probably to be referred to the horizon of dolomite mentioned as extending from Mount Morgan to Plymouth Notch.

It is probable that a bed of dolomite on the east side of Amherst Lake also belongs to this same horizon, both from the fact that its position is almost exactly in the trend line of the dolomites farther north and also because it contains a carbonaceous bed, in common with the bed on Morgan Peak, a feature of no other stratum of dolomite in town. This bed of dolomite occurs in a laminated quartzite and extends from the head of Amherst Lake to at least as far as the junction of the road on the east side of the lake with the road branching off to Plymouth Five Corners. A marble quarry (Scott Quarry) was opened on the bed, about one hundred yards east of the head of Amherst Lake, and about fifty feet of dolomite is exposed. The rock from one unusual bed about three feet thick was the main object of quarrying. This is apparently an intraformational conglomerate (or possibly breccia) consisting of subangular phenoclasts of white dolomite in a matrix of dark grey carbonaceous dolomite and forms a strikingly mottled rock. The stratum is between two larger beds of white dolomite. The grey and white mottled rock was used as an interior building stone but owing to the prevalence of joints, large blocks were difficult to obtain and quarrying was abandoned many years ago. Two kilns were built to utilize the quarry waste for producing quick-lime.

[1] Dale, T. N., U. S. G. S. Bull. 589, p. 29.

UPPER QUARTZITE

The uppermost distinct formation of the group in the Morgan Peak section, in northern Plymouth, is a dark brown or black, plicated, quartzose mica schist. This rock somewhat resembles the overlying Pinney Hollow Schist in structure and texture, but is much less chloritic and in some places contains so much fine black coloring matter as to resemble a true phyllite. The rock, when exposed transverse to the schistosity, shows many fine laminæ composed alternately of granular quartz and mica. The schist has very evidently yielded to pressure, for it is intensely wrinkled and folded in small isoclines in most of the section. The thickness, which is about three hundred feet on Morgan Peak, is probably augmented by this crumpling, and the thickness is somewhat less near Grass Pond farther south. The formation can be traced only as far as the kame deposits in the vicinity of Plymouth Notch, where it is covered.

The section immediately underlying the Pinney Hollow Schist in the region east of Plymouth Notch, is quite different from that described above. On the west side of the crest of Wood Peak quartzites and phyllite outcrop between two areas of the Pinney Hollow Schist, and these can be traced southward along the eastern border of the "older Cambrian" group for about three miles, to Blueberry Mountain, where the character of the formation changes. The quartzites on Wood Peak and East Mountain are of two principal types, interbedded; a pale brown or buff-colored variety with a slaty cleavage, and a grey or pale brown massive variety in beds about two feet thick. At the base of the Pinney Hollow Schist, and above the quartzites, is a few feet of phyllite overlying a bed of light grey dolomite about three feet thick and which outcrops between the Pinney Hollow road and Blueberry Mountain. The dolomite has been explored by trenching on the Lynde farm, on the south side of the road from Moore's Ponds to Plymouth Five Corners, and for a distance of about two hundred yards along the strike the bed has been laid bare. A trial kiln of the rock from this bed was roasted, but very little was done to exploit the deposit.

In the region south of Solitudus Mountain, the Pinney Hollow Schist is underlain by a very thin-bedded quartzite or quartzose schist which extends west to the Black River, and overlies the conglomerate on the east side of Dry Hill. The rock of this section has essentially the same mineral composition throughout, but the rock structure varies locally from a much plicated, crumpled schistose type, as that on the south slope of Solitudus Mountain, to a type with excellently developed slaty cleavage as that on the east slope of the hill east of Tyson.

THE PINNEY HOLLOW SCHIST

During the preliminary examination of the rocks of Plymouth, the formation herein named and described as the Pinney Hollow Schist was first examined at several excellent outcrops a few yards east of West Bridgewater village. Subsequently it was found that the formation was much more typically exposed in Pinney Hollow from the Pinney Hollow School westward nearly to Plymouth Village, and it was consequently named from that locality.

The formation is limited above by the Ottauquechee Phyllite and below by the "older Cambrian" brown quartzite or dark quartz-mica schist. Little variation was noted within the formation from western Bridgewater to southern Plymouth, and it is apparently a persistent and well-defined lithogic unit in this region. The thickness of the formation is variable, but in much of its exposure in Plymouth, is in the order of magnitude of 3500 feet. This may, however, be too large, since folding and thrusting has caused local thickening.

The rock is consistently a pale green quartz-chlorite-mica schist. Secondary movements, following those which induced schistosity, have often resulted in the formation of an incipient, poorly developed, slip cleavage inclined at about eighty degrees to the schistosity. Practically no indication of bedding is present in the schist except at the contact with the overlying and underlying formations. At these horizons the principal schistosity is

clearly parallel with the bedding, and inasmuch as the other formations of this part of the section all show many evidences of similar relation of schistosity to bedding throughout, it is reasonable to assume that the plane of schistosity is likewise approximately the plane of bedding in the Pinney Hollow Schist. The schist was, however, obviously non-competent to deformation. Minor zones of shearing and thrusting are common especially in that part of the formation having the greatest apparent thickness, *i.e.,* the part of the belt of outcrop which has the greatest width. The development of the secondary slip cleavage is likewise more or less confined to this part of the belt of outcrop and the schist is more distinctly platy or with slaty cleavage in other parts of

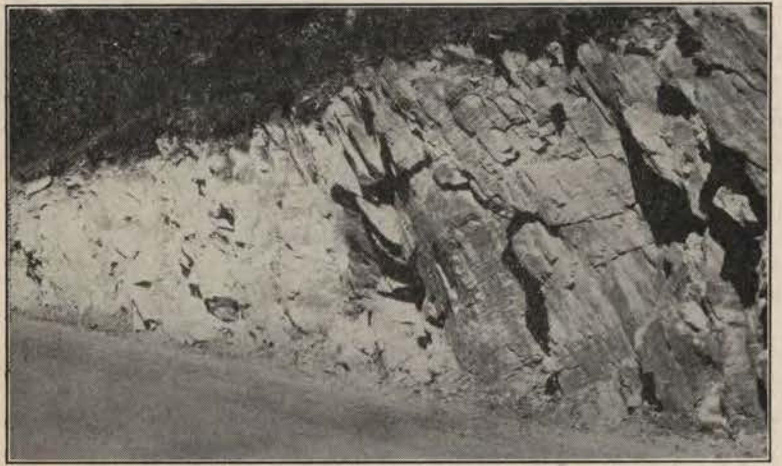

FIGURE 6.—Pinney Hollow Schist, West Bridgewater. Note the small wrinkles showing partially developed cleavage normal to the schistosity.

the belt. The Pinney Hollow Schist was observed in Ludlow to the south of Plymouth and in Stockbridge to the north, in both places quite similar to the rock in Plymouth.

Megascopically, the typical Pinney Hollow Schist is pale green and thinly laminated, often with minute crenulations, in the general plane of schistosity, passing into lines of slip cleavage. Distinct layers of quartz and the micaceous minerals, chlorite and sericite, visible and magnetite grains are often of sufficient size to be recognized. Other visible accessory minerals are rare.

At one locality in Plymouth on "Blueberry Hill" east of the head of Amherst Lake and near the base of the formation, a few outcrops showed staurolite, cyanite and magnetite developed as metacrysts in the otherwise normal schist. This porphyritic phase is very local in occurrence and is undoubtedly due to metamorphism at a higher temperature than that affecting the normal schist. No intrusives were found in place nearby, but granite blocks are present in the general vicinity and it seems probable that intrusions may be responsible for this special phase, although the exact conditions are not known. The staurolite occurs as well-defined crystals about four millimeters in cross-section and showing the characteristic combination of prism and *b* pinacoid. Magnetite is very abundant in the form of small octahedrons about one millimeter across and the cyanite is less common, as stubby nearly rectangular crystals exhibiting two excellent cleavages nearly at right angles. Both the staurolite and cyanite are black and show abundant small carbonaceous inclusions with definite arrangement in the crystals.

A second uncommon rock type found in the Pinney Hollow Schist was a limestone outcropping in a small gulch beside the north raise of "Foxes' Mine" in Plymouth. The limestone is stratigraphically very near the top of the formation and occurs in the schist as small lenses only a few inches across. The rock is very impure and contains many small patches of pyrite, probably mineralization from the same solutions which produced the nearby gold-quartz veins. The extremely local distribution of the limestone makes it of very little stratigraphical importance in this case.

Microscopically, the typical Pinney Hollow Schist shows very little more than can be seen by the unaided eye. The lamination is of the order of magnitude of one millimeter or less. Quartz is abundant as anhedral grains about one-tenth of a millimeter in diameter. The grains are very even in size and have obviously been granulated, often showing strained extinction under crossed nicols. Occasional inclusions of tiny flakes of chlorite or sericite or grains of magnetite were noted, but in general the quartz is clear. Chlorite with sericite or muscovite is abundant in intimate mixture of small flakes having a parallel orientation and forming laminæ between the laminæ of quartz grains. Magnetite is abundant throughout, as very small grains and patches elongated in the plane of schistosity. Tourmaline occurs as occasional small pleochroic crystals similar to those observed in the Bethel, Missisquoi and other schists of the region. More rarely zircon is present as primary, rounded, clastic grains and often forms pleochroic halos in the chlorite. Irregular patches of calcite and crystals of garnet and apatite are still less common as accessory minerals.

Small veinlets of granulated vein quartz are common throughout the schist and in several places are very abundant, as on Morgan Peak on the Plymouth-Bridgewater line. The quartz does not, however, take the form of the lens-shaped masses

so common in the younger Bethel Schist. The intrusive relation of the quartz is abundantly illustrated by cross-cutting veins. The only other intrusive found in the Pinney Hollow Schist was a granite, which will be described in detail in another part of this report.

THE OTTAUQUECHEE PHYLLITE AND QUARTZITE

The group of rocks overlying the Pinney Hollow Schist has heretofore never received recognition as a distinct formation, but because of its extensive outcrop in Bridgewater and northern Plymouth, it is considered advisable to name and define it at this

FIGURE 7.—Ottauquechee Phyllite above, Quartzite below.

time. The most typical exposures are found in the Ottauquechee River valley about halfway between West Bridgewater and Bridgewater Corners, and consequently it is proposed to name the formation after this stream. The formation is limited above by a quartz-chlorite-mica schist (the Bethel formation) and grades into the latter through a transition zone about two hundred feet wide. This zone is made up of small beds composed alternately of phyllite and chlorite schist. The exact contact of the Ottauquechee with the underlying Pinney Hollow Schist was not found, free of cover, at any point, but could be located within a few feet at several localities and is evidently a sharp contact, or one with a very narrow transition zone at the most. Two rock types in intimate association are typical of this formation, a massive, *slate-grey quartzite* and a dark grey or *black phyllite*. These are in distinct contrast with the green schists above and below, *i.e.*, to the east and west, and are readily distinguished from them. The formation outcrops in a north-south belt, from one to one and a half miles wide, and is conformable to the underlying Pinney Hollow Schist.

The quartzite occurs in sharply defined beds from a few inches to ten feet in thickness, interstratified with the phyllite which makes up the major part of the formation. Veinlets of granulated white quartz, from one-half inch to two inches in width, are very common in the quartzite and strike a sharp color contrast with the dark rock. The veinlets are clearly cross-cutting in many instances and are altered vein-quartz intrusives. Stringers of vein-quartz are also present in the phyllite but are very irregular in outline, in direct contrast to the veins in the quartzite which have relatively straight, parallel walls. The veins in the quartzite are of such uniform distribution and persistent occurrence as to be characteristic of the formation everywhere. The quartzite is composed of two essential substances: Granulated quartz and black coloring matter. The latter is concentrated in different proportions in successive small layers so that much of the rock is laminated and the laminæ, in the order of one millimeter in thickness, range in color from pale grey to dark slate grey. Sericite and pyrite are present locally, in small quantities. The rock, at some places, has a very imperfect parting parallel with the bedding, but is usually massive. A system of jointing parallel with the strike and at right angles to the bedding, is everywhere strongly developed and occasionally a second system is present, oriented perpendicular to the strike in the vertical plane. The quartzite beds are very resistant to erosion, as compared with the associated phyllite, and appear in relief as small ridges at the more exposed outcrops. The jointing, however, has aided the reduction of the beds to small blocks and these, a foot or more in cross-section, are very common in the glacial drift of the region.

The phyllite of the Ottauquechee formation is a black, fine-grained, slightly micaceous schist with distinctly platy parting. The phyllite, as a rock type, is very uniform in appearance throughout the entire belt of outcrop. The essential minerals are quartz and sericite with black, carbonaceous coloring matter.

Light colored sandy or micaceous layers a few millimeters thick are occasionally present in the phyllite and in southern Plymouth beds of light colored chlorite-mica schists and micaceous quartzites appear in considerable numbers. The appearance of the formation in the southern section is thus in contrast with that in Bridgewater, since the phyllite is there unaccompanied by other beds than the characteristic grey quartzite. There is thus a change in the lithology of the formation from north to south along the strike and this is quite apparently due to an original difference

in sedimentation. Many of the beds of the southern section bear a superficial resemblance, lithologically, to beds in the younger Missisquoi formation, but are quite obviously in no way related to them. Near "Plymouth Kingdom" a few lenses of siderite and associated pyrite, chalcopyrite, and quartz veinlets have been found in the phyllite and prospected for iron ore. It is very questionable whether these represent altered primary sediments and they are believed by the writer to be the product of the secondary introduction of these minerals into the country schist.

The phyllite and characteristically associated grey quartzite is believed to represent deposits of carbonaceous shale and sandstone in the northern part of the belt, grading southward into more sandy and less carbonaceous facies.

BETHEL SCHIST

The Bethel Schist was named by Richardson[1] in 1924 and briefly described by him at that time. The same author had previously called that formation by the group name the "Hydromica Schists" but this name, like the corresponding "Talcose Schist" of Hitchcock which included the Bethel Schist among several others, is unsatisfactory because the nature of the name leads to confusion with other schists of similar lithology but of different age and origin.

The continuity of this formation from its type locality in the western part of the town of Bethel to the Plymouth-Bridgewater area was established in the field seasons 1925-26 and the formation traced as far south as the Plymouth-Ludlow line. The lithology varies somewhat along the strike, but on the whole the formation is a well-defined unit bounded by the Ottauquechee Phyllite on the west and by the Missisquoi group of schists on the east. The nature of the contact between the Bethel Schist and the Ottauquechee is especially well shown in the series of exposures on the hillside north of the Ottauquechee River, about two miles west of Bridgewater Corners. At this locality the interbedding of the phyllite and mica schist is clearly shown over a zone of about one hundred yards width across the strike.

Richardson[2] has described the Bethel Schist as

> ". . . . 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."

This generalized description applies very well to the formation as it appears in the Bridgewater-Plymouth area. The rock

[1] Richardson, C. H., Rpt. Vermont State Geologist, Vol. XIV, 1924, pp. 82-83.
[2] *Ibid.*

is a green-grey, quartz-chlorite-muscovite schist, locally garnetiferous, but with few other important accessory minerals.

Quartz, as small (one-third milimeter), angular, anhedral grains segregated in layers one millimeter or less in thickness, makes up at least one-half of the rock. Between the quartz laminæ are layers of the micaceous minerals, chlorite and muscovite. The latter, mostly in the form of sericite, occurs as an intimate mixture of tiny shreds with occasional patches of light green, clear chlorite up to one-half millimeter in diameter and laths of muscovite of the same order of magnitude. The orientation of the tiny flakes of micaceous minerals, parallel to the coarser laminæ of quartz and mica, gives the rock its schistosity. The most common persistent accessory mineral is magnetite in grains less than one-half millimeter across and usually with anhedral form, although some of the grains are subhedral indicating partially formed octahedrons. The mineral is readily attracted to a magnet and is thus probably magnetite although the presence of titanite as occasional cloudy grains suggests that some ilmenite may be present with the magnetite. Microscopic prisms of tourmaline and less frequent rounded zircons are scattered through the schist. Garnets are locally abundant as in the section exposed along the Ottauquechee, just west of Bridgewater Corners, where they make up fully one-tenth of the rock. The garnets are dark brown (almandite?) and occur as imperfect dodecahedrons, usually less than one centimeter in diameter. Biotite is occasionally present, although not in noticeable quantities in the formation as a whole.

In addition to the finely granular quartz in the laminæ, small quartz lenses are very common in the Bethel Schist. These lenses, as they appear on the surface, average about six inches long and two inches wide at the widest part, tapering off to a point at either end. They are oriented with the longest dimension parallel with the strike of the enclosing schist, *i.e.,* approximately north and south. The third dimension shows that the mass is usually greatly elongated parallel with the dip of the schistosity, so as to form a columnar mass with lens-shaped cross-section.

Although these masses are very common in all parts of the formation, often several to the square yard, their general irregularity of distribution in space and occasional presence of a cross-cutting stringer of what seems to be the same material, suggests an intrusive origin and that these represent the remains of numerous quartz veins intruded prior to, or during, the final metamorphism of the region. Two other modes of origin have been suggested: That they represent metamorphosed pebbles of vein quartz or quartzite, and that they originated by recrystallization and segregation of quartz in the process of metamorphism of the

original shale. Neither of the two latter theories explain the observed facts as well as that advocated above.

THE MISSISQUOI GROUP

The term Missisquoi Group, as used by Richardson, is assumed to include all the metamorphosed sedimentary formations between the base of the Ordovician formations and the top of the Bethel Schist, in central Vermont. This term was introduced by the above author[1] in 1918. The name Missisquoi has unfortunately since been used by Kieth and Raymond[2] to designate an entirely different formation, of Cambrian age, found near Highgate Falls, Vermont. It must be made clear at the outset that these formations are not in any way related. The name is taken from that of the Missisquoi or Missisco River which rises in the town of Lowell in northern Vermont and flows northward into Canada, later swinging south again into Vermont and emptying into Lake Champlain.

The age of this formation, or group of formations, has been referred to the upper Cambrian by Richardson, in the course of his work in central Vermont. But it must be emphasized that the age of the Missisquoi, in Vermont, has not been determined on the evidence of fossils.

> "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."[3]

Thus, although it seems highly probable that these are of late Cambrian age, no direct proof can be offered. As will be pointed out below, the formation unconformably overlying the Missisquoi is Lower Ordovician in age.

Although in a broad way the formations which go to make up the Missisquoi Group have much in common, they differ considerably in minor details. Richardson has subdivided the group into two parts, a sericite schist and a sericitic quartzite. In addition to these, local occurrences of phyllite, chlorite schist and hornblende schist are also cited. The Missisquoi as best exposed in Bridgewater does not lend itself to such a subdivision, but may be resolved into a micaceous quartzite which makes up the most of the upper half (similar to that of Richardson) and a series of thin-bedded schists of considerable variety, making up the lower part.

[1] Richardson, C. H., Rpt. Vermont State Geologist, 1917-18, p. 138.
[2] Raymond, P., Rpt. Vermont State Geologist, 1923-24, p. 137.
[3] Richardson, C. H., Rpt. Vermont State Geologist, 1923-24, p. 101.

THE UPPER MISSISQUOI

The upper Missisquoi quartzite is well exposed on Richmond Hill, Southgate Mountain, and Cobb Hill in Bridgewater, where large outcrops smoothed by glacial erosion are common. Throughout most of this section, but particularly in the vicinity of Bridgewater Village, numerous narrow zones of hornblendic rock are present in the quartzite and sometimes form a considerable part of the whole, but for the most part the formation is a fairly uniform quartz-mica schist.

Much of the quartzite bears a superficial resemblance to gneiss in the arrangement of light and dark minerals, particularly where the rock has been subjected to isoclinal folding on a small scale, but feldspars are rare or absent in most specimens and the chief minerals are quartz, white mica and biotite, with garnet forming an important constituent at some localities. The presence of hornblende in the upper Missisquoi is a local feature of the formation near Bridgewater Village. The hornblendic rock occurs both as dike-like bands having well-defined borders and as bands which show a gradual decrease in the proportion of hornblende from the center outward into apparently normal country rock. The presence of the hornblendic rock is interpreted as being due to the presence of mafic intrusives close beneath the surface of this area and a consequent higher grade of metamorphism, and introduction of mafic material, in the quartzite.

A study of thin sections of the typical upper Missisquoi shows the quartz to be the predominant mineral and it comprises about four-fifths of the rock. The micaceous minerals are second in importance. Biotite and muscovite occur as isolated laths scattered through the rock and chlorite is present as irregular pale green patches associated with the biotite. Occasional magnetite grains are associated with the chlorite. Tourmaline is sparingly present as short, thick, well-rounded prisms. The quartz of the ground mass is granulated and appears as a mosaic of uniformly small, interlocking, angular grains cut by all the other minerals with the exception of the tourmaline which is apparently present as primary clastic grains. The parallel orientation of the micaceous minerals serves to give the rock its imperfect schistosity.

THE LOWER MISSISQUOI GROUP

The varied schists comprising the lower portion of the Missisquoi Group are best exposed in the bed of the north branch of the Ottauquechee River, from the northeast base of Freestone Hill westward through Chatauguay nearly to the Sherburne town line. The section here uncovered is nearly continuous across the strike, for a distance of about three miles. In general the individual beds of schist are but a few feet in thickness and adjoining beds are often of extremely contrasting lithology. The considerable breadth of the exposed section and the enormous number of rock varieties displayed, renders impractical any attempt to describe them in detail. It is the intention of the writer to describe below some of the more typical and abundant rock types, in order to convey an impression as to the general nature of the group. Some of the more unique beds can be traced for a considerable distance along the strike, but none is sufficiently persistent to serve as a distinct horizon marker and thus exact correlation of a section in one part of the town with a detached section in another, is highly conjectural at best. A careful study of the area would very probably yield information which could be used in correlation, but such a study would be quite out of place at the present time when much remains to be done in delimiting and mapping the broader units of the section in nearby areas.

The general mineral assemblage of the lower Missisquoi is well defined and consistent throughout the group, although adjoining beds may vary in their individual mineral composition. The four characteristic minerals are quartz, garnet, biotite and sericite. A few other minerals are present in lesser amounts, viz., chlorite, magnetite, hornblende, pyrite and muscovite. Still others are occasionally present, although not noticeable in a megascopic examination. Quartz is the most persistent mineral throughout and very often is found to be the major constituent of individual strata. Sericite, the next most *noticeable* mineral, is nearly always present on planes of parting in the schists and imparts a silvery luster to fresh surfaces. Garnet is very abundant and is usually associated with biotite and a minor proportion of chlorite. It is of interest to note at this point that Dr. Richardson, in verbal communication with the writer, has commented upon the presence of much biotite in the Missisquoi of Bridgewater, as contrasted with the lack of this mineral in rocks of the same group to the northward. This is probably due to a difference in environment during metamorphism and a reaction of earlier sericite with chlorite to form the biotite.

The majority of the lower Missisquoi rocks fall in one of four rock types: garnetiferous mica schist, micaceous quartzite, carbonaceous mica schist and chlorite schist, although the latter is considered in most instances to represent intrusives rather than true sedimentary rocks of this group. The number of individual variations within these main types is legion.

The quartzites are never very pure, but always contain admixtures of biotite, sericite and sometimes garnet. They are often finely laminated both with respect to color and distribution of minerals. In general the parting is ill defined, since the micaceous minerals are neither present in sufficient quantity, nor are they sufficiently segregated, to produce well-defined planes of weakness. The best exposures of the quartzite phase of the lower Missisquoi are found in a zone about a quarter of a mile east of the upper contact of the Bethel Schist. In this zone are the outcrops west of Chatauguay, lower Dailey Hollow, west of Bridgewater Corners, and the western side of Hale Hollow.

The carbonaceous mica schist of the lower Missisquoi is found in isolated strata interbedded with the quartzites and chloritic schists, but is also found in a fairly well defined belt passing through Chatauguay, lower Dailey Hollow, Bridgewater Corners and Hale Hollow, following approximately the eastern line of outcrop of the quartzites mentioned above. Lithologically, the carbonaceous mica schist resembles the Ottauquechee Phyllite except that the parting is not as pronounced as in the latter, and garnets are occasionally present in addition to the essential quartz, sericite, and black coloring matter. Thin layers of light colored chlorite-sericite schist are sometimes present in the beds of black schist. The carbonaceous schist is interpreted as representing metamorphosed black shales with occasional interbedded sandy or non-carbonaceous, shaly layers.

Interbedded with the quartzites and carbonaceous schist are beds of garnet-sericite-chlorite schist of considerable variety. The usual color of this type of rock is greenish grey spotted with black biotite and brown or pink garnets. The ground mass of the rock is composed of granular quartz and poorly crystallized micaceous minerals, and is of quite uniform appearance in any one bed. No marked zone of outcrop of this rock is apparent, but it is quite as abundant, scattered through the group, as are the micaceous quartzites or the carbonaceous schist.

THE WAITS RIVER AND RANDOLPH FORMATIONS

The Waits River Limestone and Randolph Phyllite, of central Vermont, have been the subject of an extensive study by Dr. C. H. Richardson, of Syracuse University, during a period of more than twenty years. From near Lake Memphremagog in Canada, where the beds contain fossils of Middle Ordovician age, the beds have been traced southward in a continuous belt as far as the area at present under discussion. At several localities in Vermont, fossils, mostly graptolites, have been found in the metamorphosed shales and limestones and in all cases these indicate an Ordovician age for the formations.

The locality in the Ordovician belt which has furnished the most extensive graptolite fauna is the Castle Brook section, Magog, P. Q. The species found there have been listed by

Dawson,[1] Gurley,[2] Richardson,[3] and Ruedemann.[4] Ruedemann, whose work is the latest of the four and generally accepted as authoritative, places the age of this fauna as just below the Utica, *i.e.*, upper Middle Ordovician. The same author places the age of the slate at Montpelier, Vermont, as Beekmantown upon his identification of Tetragraptus amii among specimens found by C. H. Richardson at that locality. The formation in Northfield has likewise yielded a graptolite, Phyllograptus angustifolius, of Beekmantown age. At most of the other Vermont localities which have furnished graptolites, the rocks have been so metamorphosed as to render the determination of species impossible and in most cases even the genus is indeterminate. This is particularly true in the towns just north of the area under discussion. But while the exact age of the formations is often in question, it remains certain that they are, at least, definitely Ordovician.

The base of the Ordovician, in some parts of central Vermont, is marked by a basal conglomerate, the Irasburg Conglomerate, but no evidence of this rock was found in Bridgewater. The exact contact of the Randolph Phyllite and the underlying formation was not observed at any locality, but was determined within fifteen feet at one point and no marked change in lithology was evident in the phyllite near the contact. The underlying formation is the upper Missisquoi quartzite and is quite unlike the phyllite, so that no difficulty is encountered in determining the lower or western boundary of the Ordovician section.

The Ordovician rocks in Bridgewater may be subdivided into two types according to lithological characteristics: The phyllite named the Randolph Phyllite by C. H. Richardson, in 1924, and a formation which ranges in composition, locally, from a siliceous-calcite marble to a calcareous quartzite and is a phase of Richardson's Waits River Limestone. The phyllite is classed by the same author as a member of the Memphremagog Group of metamorphosed shales. It must be strongly emphasized that these different formation names do not necessarily imply different ages for the two rock types, but simply a difference in lithology. The phyllite and limestone are of the same general age, as far as their outcrop in Bridgewater is concerned, for they appear interstratified in thin beds at many localities.

The phyllite is a dark grey, strongly foliated, graphitic looking, mica schist which parts readily into irregular fragments parallel to the imperfect schistosity. In addition to the essential quartz, mica, and dark coloring matter, the most abundant accessory mineral is garnet, which often makes up more than a third of the volume of the rock. The garnet crystals are from one to

1 Dawson, G. M., Geol. Sur. Can. Rpt., Vol. VII, 1894, Apen. j, p. 133.
2 Gurley, R. R., Jour. Geol., Vol. IV, 1896, pp. 294-301.
3 Richardson, C. H., Rpt. Vermont State Geologist, 1901-02, p. 97.
4 Ruedemann, R., N. Y. St. Mus. Memoir No. 1, Part 2, 1908, p. 29.

two millimeters in cross-section and are evenly distributed through the phyllite. The mica laminæ curve about the garnets and cause the uneven "fish scale" appearance of the rock surface along a plane of parting. Occasional biotite crystals are present, but are not sufficiently abundant to be characteristic of the formation. Pyrite is present as small scattered cubes often much weathered to limonite. The surface of the phyllite outcrops is black, often with numerous rusty streaks and bands of dull brown and grey, which represent original bedding. These bands usually form a considerable angle with the schistosity and are nearly vertical.

The limestone is a uniformly slate grey massive rock with no fixed lines of parting. The essential components are calcite and quartz, both recrystallized from their original form, and black carbonaceous coloring matter evenly distributed through the rock. Sericite is present as scattered shreds but in insufficient amount to produce schistose parting. Quartz grains are so abundant in some parts of the formation as to make a quartzite rather than a limestone, but calcite is consistently present and it seems advisable to refer to the formation as a whole as a limestone.

The limestone weathers readily to a *porous,* seal brown rock on the exposed surfaces and is unique in appearance among the other rocks of the area. Bedding is rarely shown in the limestone itself and is practically indeterminate except at the contacts with strata of phyllite.

On the geological map of Bridgewater the areas mapped as the Randolph and Waits River formations are divided arbitrarily so that the latter contains more than half limestone and the former includes more than half phyllite, but it must be made clear that no *sharp* subdivision along such lines is possible. The phyllite is preponderant at the base of the Ordovician and becomes decreasingly abundant in the younger strata which are composed of great thicknesses of limestone with very little phyllite.

No attempt can be made to estimate the thickness of the Ordovician section exposed in Bridgewater, because of the intense isoclinal folding everywhere present. Folding is much more intense in the non-competent phyllite and the bedding planes are usually either vertical or dipping at high angles east or west. There is often overturning of the small folds from east to west and many of them, only a few feet across, pitch northward and die away within a few feet along the strike. The strike is necessarily somewhat variable, but is consistently near N 10° E.

AMPHIBOLITES

Intrusive into the schists of the Missisquoi and immediately underlying formations are several stocks and dikes of metamorphosed igneous rock which, particularly on the weathered surface, closely resembles a diorite. An examination of thin sections shows the amphibole of the rock to be in the form of uralite, fibrous secondary hornblende, indicating that the rock is an amphibolite or more exactly an "epidotamphibolite"[1] since epidote is present in considerable quantities. Schistosity is but slightly developed in the most typical phase of the rock so that the name hornblende schist is scarcely applicable.

The major exposures of amphibolite are shown on the geological map of Bridgewater. The most important stock is that forming the peak of Bull Hill one and one-half miles north of Chatauguay, in the northwest corner of the town. The shape is approximately an oval 1,000 yards long and 500 yards wide, with the longer dimension north and south. At the southern base of the hill near the Chatauguay-Barnard road the contact of the intrusive rock with the country rock, which is here a garnetiferous mica schist of the lower Missisquoi Series, is visible for several yards along a small brook. Contact metamorphism attendant on the intrusion was apparently slight for no alteration is noticeable in the country schist except in a zone about a yard wide of somewhat finer texture adjacent to the contact. Slight textural variations are evident throughout the intrusive so that some areas are relatively coarse, with crystals up to one-half inch across, although most of the amphibolite is of fine grain (.25 inch) and with a preponderance of dark minerals.

The cross-cutting relation of the amphibolite to the country rock is very clearly shown at the contact at the base of Bull Hill mentioned above. The contact here cuts across the strike of the bedding in the garnetiferous sericite schist at angles up to ninety degrees. The east and west borders of the amphibolite body are approximately parallel to the strike of the country rock. A dike of material which is evidently a fine-grained phase of the amphibolite outcrops in the brook beside the Chatauguay-Barnard road at an elevation of 1,800 feet, south and slightly east of the main stock. The dike is thirty to forty feet wide and can be traced northwestward into the main body in a distance of about one hundred yards.

The coarsest phase of the intrusive was found near the crest of Bull Hill on the north side. This rock contained comparatively fresh feldspars, up to five mm. in cross-section, enclosed in fine-grained fibrous amphibole. No other minerals were recognized in hand specimens. The rock when examined in thin sections with the aid of the microscope, showed the following minerals: Abundant cloudy crystals of *albite* of composition about $Ab_{92}\ An_8$ as determined from the maximum extinction angles of 16 and index refraction less than balsam; abundant hornblende,

[1] Osann, Dr. A., Elemente der Gesteinslehre, 2 Halfte, p. 448, Stuttgart, 1923.

probably pargasite, in the form of long laths and bundles of fibers cutting everything except epidote and apatite; biotite common as euhedral plates and laths, sometimes fresh but often altered to chlorite; epidote common as small irregular grains usually in contact with the feldspar; apatite abundant as small prisms up to 0.6 mm. long and 0.1 mm. in cross-section; quartz and magnetite as small anhedral grains interstitial to, or enclosed by, the other minerals.

Other specimens from Bull Hill, although of finer texture, have the same essential mineral composition as that described above, namely, plagioclase, uralitic hornblende and epidote. The additional accessory minerals calcite, titanite, zircon and tourmaline were noted in other specimens. Tourmaline was very abundant in the amphibolite at the exact crest of the hill and was present both as rosettes of fibers and as sheets about two inches thick composed of very fine fibers arranged transverse to the enclosing walls. Hand specimens of the latter material resemble charcoal in superficial appearance, except for a delicate silky sheen on a fresh surface.

The small stock mapped to the south of Chatauguay and that west of Bald Mountain in southern Bridgewater are essentially of the same composition as that of Bull Hill and also bear the same relation to the country rock. A small dike on the Bridgewater-Woodstock line in Curtis Hollow, several in Bridgewater Hollow and many others, too small to be mapped, scattered through the Missisquoi formation are similar in composition to the larger stocks and are probably genetically related to them. Microscopic examination of rock from the various bodies shows that they vary only in the relative proportions of the different minerals and not in the general assemblage.

These amphibolites are considered by the writer to represent recrystalized plutonic rocks which probably had the original composition of a diorite or a gabbro. The original mafic minerals, biotite and either amphibole or pyroxene, have been recrystalized to uralitic pargasite and chlorite while the original plagioclase has been altered to albite and strongly calcic epidote.

STEATITE

At least five separate areas of steatite are present in Bridgewater and Plymouth, but all except one have a very limited outcrop. All have been prospected for commercial soapstone or talc and the rocks show the same essential composition at each locality.

The most accessible outcrop, and one which may be considered as typical, is that at the southeast base of Freestone Hill, a few yards west of the road from Briggs to Chatauguay. The steatite here was formerly quarried for local use and fresh surfaces of the rock are well exposed. The steatite is limited to an approximately circular area about fifty yards in diameter, covered on the south and east by kame deposits and bounded on the north and west by sericitic quartzite of the Missisquoi formation. The rock in the central part of the body is composed almost wholly of two minerals: talc, comprising the major portion of the rock; and ankerite, often abundant as veinlets. Chlorite is present in minor amount. The talc is locally púre and well crystallized in pale green plates, but is most often present as the massive impure mineral.

Because of the presence of ankerite or dolomite in numerous veinlets, the rock is of little commercial value. These minerals cause difficulty in quarrying and trimming the rock because of their hardness and brittleness and also lessen its resistance to heat changes. The ankerte is of scientific interest, since it gives a clue to the origin of the steatite body. Ankerite is typically a product of the metamorphism of igneous rocks and in this case gives added proof to the indications yielded by the field occurrence, *i.e.*, cross-cutting relationship and marked lithologic dissimilarity to the surrounding rock, that this body was once an igneous intrusion. Although the soapstone most probably continues with depth, the small size of the outcrop, the numerous impurities present, and the distance from a railroad all combine to render commercial exploitation quite impractical except for an extremely local use on a small scale.

Two small outcrops of steatite are present on Bridgewater Hill about a mile and three-quarters east of West Bridgewater (see map). The steatite is here enclosed in the black phyllitic schist of the Ottauquechee formation. The best outcrop is situated about one hundred yards north of the McElroy farmhouse and has at one time been prospected for soapstone. The steatite body is very small, about fifteen feet in diameter and roughly circular, judged from the appearance of the prospect pit which is now nearly filled with water. Material from a dump beside the pit shows a better, much more uniform grade of rock than that in the body north of Briggs, but some carbonates are present and locally the rock is said to be "gritty." At this outcrop the country rock is typical black phyllite with some quartzite near by, quite different lithologically from the rock at the Briggs deposit. The second outcrop mentioned above is about a thousand yards south, slightly east of the first, and is in line with the latter along the trend of the bedding of the country rock. It is very similar to the first in all ways and needs no further comment. In this same general vicinity, near the top of Bridgewater Hill, a piece of asbestos with well-developed fibers one inch in length was found by Mr. Hesleton in a piece of float in a pasture. It is highly probable that this is to be found in place near by and that the occurrence of asbestos is associated with the steatites or very closely related basic intrusions in the vicinity.

Two areas of steatite and associated rocks were found in Plymouth. A third area was mentioned by Hager in his report of the geology of Plymouth, but this could not be located by the writer. The largest body in the town outcrops in a long strip extending from the vicinity of Plymouth Five Corners southward for about two miles. The strip is about eight hundred feet wide near the northern end and becomes slightly narrower to the south. The country rock is the Ottauquechee phyllite and the intrusive cuts across the strike of the latter at a small angle (see map). The best exposure in this area is situated in the bed of a small brook, a few yards north of the "Five Corners." At this locality some exploration has been carried out by sinking a pit into the intrusive. The rock differs considerably from that at the Bridgewater localities in that much more chlorite is present, especially on the border of the intrusive. In the prospect pit a fibrous amphibole is abundant in irregular streaks and crystalline aggregates. The amphibole is tremolite rather than actinolite, because of the small iron content, *viz.*, 2.34 per cent FeO. A low content of water indicates that little alteration to talc has taken place. Most of the amphibole occurs in a massive, pale green rock composed of radiating bundles of short fibers, but some is distinctly asbestiform of a type often called "slip fiber," arranged in layers of overlapping fibers about six inches long, approximately parallel to the walls of the sheet. The fibers have little strength, owing to an excellent basal parting transverse to the prismatic needles of the mineral.

The amphibolite is of limited distribution in the center of the body and is surrounded by a zone of dark green, highly chloritic rock containing irregular lighter patches bearing a small proportion of talc with some ankerite and chalcopyrite. Near the border of the intrusive the rock is more chloritic and less talcose, but has no definite planes of schistosity and is quite unlike any other chloritic rocks in the region. The entire assemblage is much like other outcrops of talc-bearing rocks in Vermont, as described by E. C. Jacobs,[1] but the zones defined by him are not well developed in this case. The interior zone of carbonate-bearing talc, similar to that in the Bridgewater deposits, is noticeably absent. The tremolitic rock possibly represents the original nature of the intrusion, but is more probably a halfway step in the formation of talc by hydrothermal alteration of an original pyroxene or olivine-bearing rock.

In tracing the zone of outcrop from the "Five Corners" southward, the massive chlorite-talc rock was found to persist in

[1] Jacobs, E. C., Rpt. Vermont State Geologist, 1913-14, pp. 402-3.

a few scattered outcrops, and much float, for about two miles. A distinct outcrop of steatite with dolomite (or ankerite) very similar to those in Bridgewater crosses an east-west road 2600 yards south of the "Five Corners" and is a part of the same belt.

An area somewhat similar to that described above, appears in the extreme southeastern corner of Plymouth, in the Missisquoi formation. Like that at the "Five Corners," much of the rock is very chloritic, but at the north end of the area (see map) near "Plymouth Kingdom," a small patch of steatite was at one time exploited. The blocks of soapstone, after quarrying, were trimmed by a saw driven by water power from a nearby brook.

It is evident from the above that the writer considers the described deposits of steatite to be the product of metamorphism of plutonic rocks rich in magnesian minerals. This theory is also advocated by E. C. Jacobs,[1] C. H. Hitchcock,[2] J. A. Dresser,[3] and M. E. Wilson[4] for other similar or identical deposits in Vermont and the Eastern Townships of Quebec. These deposits are part of a series of steatite and serpentine outcrops extending along the eastern Appalachians from Gaspe to Georgia and are probably quite different in origin from those of Ontario or of western New York State. An excellent résumé of the present knowledge of the talc deposits of North America is given in the paper by Wilson, cited above, and comparison of the various origins proposed, may be obtained from that source. In the case of the deposits in Bridgewater and Plymouth, it may be briefly stated that there is no indication of the derivation of the talc from the metamorphism of a sedimentary dolomite, and the theory of origin from the hydrothermal alteration of a chloritic mica schist (originally sedimentary) is untenable, since the steatite is here found enclosed in black phyllite, carbonaceous quartzite, or sericitic garnetiferous quartzite, often with beds of varying lithology, all of which would probably have some noticeable effect on the final appearance of the steatite, if formed in this way.

The age of the steatite intrusions can not be determined with certainty, but is probably as suggested by Wilson (preceding citation, page 10) middle Paleozoic. Within the Bridgewater area the steatites were not found in the Ordovician rocks, but are present in the youngest Cambrian strata, and their degree of metamorphism is interpreted as indicating an age greater than Devonian. The writer was unable to find mention of a steatite body, in either Quebec or Vermont, which was found in rocks known to be Ordovician or younger, hence this may be taken as indica-

[1] Jacobs, E. C., prec. cit., 1914.
[2] Hitchcock, C. H., Jour. Geol., 1896, p. 58.
[3] Dresser, J. A., Can. Min. Inst. Trans., Vol. XII, 1909, p. 177.
[4] Wilson, M. E., Talc Deposits of Canada, C. G. S. Ec. Geol. Series No. 2, 1926.

tion, although not a proof, of a pre-Ordovician, *i.e.*, a late Cambrian, age for the steatites.

GRANITE GNEISS OF DRY HILL

On Dry Hill northwest of Tyson, and west of Amherst Lake, an area of granite gneiss about a quarter of a mile wide and one and a half miles long forms the crest and northern spur of the hill. The area is bordered on the east by conglomerate and on other sides by a black, porphyritic, albite, mica schist. As far as could be determined, the area is isolated from any other bodies of gneiss in the vicinity and is confined to an elongated area of outcrop in the general line of strike of the enclosing rocks (see map). From the areal distribution and lithology of the gneiss, it is believed to be an igneous intrusion along a zone of weakness between the relatively competent conglomerate and the underlying schist. On the west slope of Soltudus Mountain north of the area of gneiss, a small sill of metamorphosed granitic material appears in the albitic schist and strongly suggests a connection with the gneiss across the valley, thereby strengthening the above hypothesis.

The problem of intrusion is vital in this case, since the granite gneiss bears a superficial resemblance to some of the pre-Cambrian gneisses in the Mount Holly Series. In detailed mineral composition, however, the Dry Hill gneiss does not coincide with the pre-Cambrian ones. It is evident that at first sight the gneiss might be considered as pre-Cambrian and the overlying conglomerate to be a true basal conglomerate of the Cambrian, but this is believed not to be the case since a complicated system of faults would be required to explain the observed relations on this hypothesis.

The typical gneiss is not distinctly banded, but is streaked with small discontinuous layers of chlorite and mica with rough parallel orientation. Some of the gneiss in the central portion of the outcrop shows augen structure on a very small scale. The minerals visible on microscopic examination are feldspar, apparently a potash feldspar, quartz, chlorite and white mica. Examination of the rock by aid of a microscope shows the common feldspar to be mostly microcline in anhedral grains up to 1.0 mm. in cross-section. Albite is occasionally present as clear, fresh crystals, and quartz is relatively abundant, likewise as clear anhedral grains. Chlorite is sufficiently abundant and persistent as to be classed as an essential mineral and is present both as large crystals and as small rounded blebs in the feldspar. Muscovite and magnetite are abundant accessories. The most notable contrasts between the minerals of this gneiss and the pre-Cambrian type are in the abundance of microcline and lack of epidote and apatite in the former.

Near the contact of the gneiss with the conglomerate on the east the grain of the gneiss is visibly finer and the rock less chloritic than in the center of the mass, and thus suggests an intrusive rather than erosional contact. This is further borne out by the fact that most of the boulders and pebbles in the base of the conglomerate are quartzite and not gneiss. The age of this gneiss is in question. The degree of metamorphism would suggest an early Paleozoic age, if the mode of origin of the mass has been correctly interpreted, and this represents an intrusion of granitic composition.

VEIN QUARTZ

Vein quartz and more rarely pegmatite, is very common in the metamorphosed Paleozoic sediments of Plymouth and Bridgewater and somewhat less abundant or less obvious in the pre-Cambrian rocks. The quartz has, in practically all cases, undergone obvious granulation and has been involved in the movements accompanying the metamorphism of the region. The quartz veinlets are absent from both the metamorphosed and unmetamorphosed igneous rocks, but are very abundant in the metamorphosed shales of the Pinney Hollow, Ottauquechee, and Bethel formations.

In most instances the vein quartz is intrusive in the planes of schistosity of the country rock, but is occasionally cross-cutting, particularly in the more massive types such as the grey quartzite associated with the Ottauquechee phyllite. The usual size of the quartz veins is small, two or three inches across, but occasional well-defined veins up to thirty inches, and irregular masses up to ten feet, across were observed. As contrasted with these maximum dimensions, many veinlets of microscopic size were also noted. Many of the bodies of quartz are lens shaped, as if distorted by movement, but it is very difficult to determine whether such structures are purely secondary or whether they are in part primary and determined by the structure of the rock into which they are intruded. The quartz lenses described in connection with the Bethel Schist are a case in point.

Orthoclase feldspar is rarely present with the granulated quartz as crystals up to an inch across and in the largest veins metallic sulphides and native gold are occasionally developed. The common sulphides are galena, chalcopyrite and pyrite, with the former most abundant.

PLYMOUTH GRANITE

The occurrence of granite on the south slope of Morrison Hill in Plymouth has been described by both Hager[1] and Dale[2]. The outcrop is situated about one-half mile northwest of the Pinney Hollow road and an equal distance due west of the Pinney Hollow schoolhouse, east of the road to the abandoned Morrison farm at about the 1,500 foot contour level.

The timber has been recently cut from the hillside in the vicinity of the granite and a dense growth of underbrush obscures the limits of the outcrop but the shape is approximately that of a lens, at least 500 feet long and 100 feet wide at the widest part with a vertical exposure of about thirty feet. The igneous intrusion entered along the plane of schistosity of the Pinney Hollow Schist so that it is essentially a concordant body with very little cross-cutting along the visible contact. The country rock is well exposed in contact with the granite on the north, or upper side, of the lens. Several dikes of aplite about one foot wide extend at right angles from the intrusive a few feet into the country rock and in one spot stringers of the aplite surround small blocks of the schist. These dikes are apparently intruded along lines of tension jointing at the crest of the low arch of the upper side of the lens. A few aplite dikes were also found in the schist about 600 feet northwest of the main granite mass.

The intrusive is considered by T. N. Dale to be a quartz monzonite but according to recent practice in petrography would be considered as an albite granite or possibly a granodiorite or quartz diorite. It is, however, convenient to speak of the rock as a granite since it is a holocrystalline rock composed almost entirely of quartz and feldspar and with no mafic minerals. The essential composition, computed by the Rosiwal method, is: Quartz 30.3 per cent, albite 60.5 per cent, microcline 5.7 per cent, microperthite 1.6 per cent, muscovite 1.7 per cent, and apatite 0.1 per cent. In thin section the quartz is present as comparatively clear anhedral grains; the plagioclase (albite ranging to oligoclase) as anhedral grains considerably altered to sericite with some calcite and kaolinite; the microcline as anhedral grains showing little alteration; the microperthite as much altered grains with considerable sericite and kaolinite; the muscovite as well-defined laths interstitial to the quartz and feldspar; and apatite as occasional small euhedral prisms.

Hand specimens of the rock are white with no dark minerals. The feldspars are milky and the quartz colorless to pale blue making up a medium-grained (0.2 inch) rock of granitic texture.

[1] Hitchcock, C. H. and E., Jr., and Hager, A. D., Rpt. Vermont State Geologist, Vol. II, 1861, pp. 740-741.
[2] Dale, T. N., Commercial Granites of New England, U. S. G. S. Bull. 738, pp. 160-161.

Resemblance to the Bethel granite of Bethel, Vermont, twenty miles north of Plymouth, is very marked.[1] At the border of the Plymouth intrusive the texture is very fine, approaching felsitic, and indicating marginal chilling. Contact metamorphism is almost absent; consisting as it does of the silicification of the adjoining mica schist for a distance of only two or three inches. This silicification destroys the schistosity of the country rock indicating metamorphism of the latter prior to the intrusion of the granite.

A dike of essentially the same material as the granite described above is located on the south slope of Soltudus Mountain in Plymouth, one mile south of the "Old Notch." The dike is about fifteen feet wide and may be traced as a line of subangular blocks, in a N 30° E direction, for several yards up the wooded hillside.

The dike rock has a composition: Quartz 26 per cent, albite 50.9 per cent, microcline 7.8 per cent, microperthite 7.1 per cent, muscovite 6.1 per cent and pyroxene (augite) 1.9 per cent. The most important differences between this rock and that previously described are in the greater proportion of potassic feldspar to albite and in the presence of a small amount of light colored pyroxene. The texture, size of grain, and color are all the same as those of the granite on Morrison Hill.

Numerous loose blocks of the same granite are present in the glacial drift in the amphitheater-like valley west of Blueberry Hill and southeast of Soltudus Mountain in Plymouth, about three-fourths of a mile east of the above-mentioned dike. No outcrop of granite was found in place in the vicinity.

The age of intrusion of similar Vermont granites has been placed as Devonian by several writers. Dale considers the age to be "probably the end of the Devonian or Carboniferous." Ells in writing of the granitic intrusives of the Eastern Townships of Quebec, just north of Vermont, advocates the theory that "it is probable that the age of the granites is not far from the close of the Silurian period."[2] The most accurate age which can be assigned from a study of field relations of granite and country rock in this part of Vermont, is post-Ordovician, for the granites cut rocks of Ordovician age. It seems reasonable, in view of the fact that no crushing or other sign of metamorphism is evident in the Plymouth granite that the age of intrusion is coincident with or slightly later than the orogenic movements of the Appalachian Revolution generally recognized as having taken place along the Green Mountain axis. On this line of reasoning the age could be put as late Paleozoic with reasonable cer-

[1] Dale, T. N., Commercial Granite of New England, U. S. G. S. Bull. 738, 1923, p. 156.
[2] Ells, R. W., Ann. Rpt. G. S. Can., 1894, Part J, p. 69.

tainty, especially if the diabase dikes, which have been found to cut the granite at Bethel, are correctly dated as Triassic.

CAMPTONITE AND DIABASE DIKES

Dikes composed of slightly altered mafic minerals and which are younger than any of the other lithified formations, are locally common in Plymouth and Bridgewater. About thirty dikes were studied in place within the area and many loose blocks of others were noted in the glacial drift at numerous localities. The size of these bodies varies from a width of fifteen feet and length of over fifteen hundred feet in the larger ones, to a width of less than a foot and traceable length of only a few feet, in the smallest. The width of the average dike is about eighteen inches. Most of them trend approximately east and west across the strike of the country schists, but no exact system of orientation was observed. The general color is quite dark, either black, greenish black or dark grey, although one unique individual was found which was light in color in its central portion. Textural variations range from very fine aphanitic to coarse porphyritic, the latter with phenocrysts more than 3 cm. long. Jointing is very common in all the mafic dikes and they are readily reduced to small blocks by erosion. Weathering in turn reduces these to spheroidal lumps which constitute the usual residue along the line of surface outcrop of the rock. The dikes were found to be most common in the younger formations of the section, particularly the Missisquoi Group, and none was found in place in the pre-Cambrian rocks, although similar dikes have been found intrusive into the Mount Holly Series in nearby areas.

The dikes are divisible into two distinct types, according to their mineral composition, as determined by aid of the microscope. These are respectively *camptonites,* characterized by the presence of the hornblende, barkevekite, with feldspar close to calcic andesine; and *diabase,* characterized by augite with feldspar about labradorite in composition. It is often difficult to distinguish between these two rock types by a megascopic examination, but the camptonites are usually porphyritic with phenocrysts of barkevekite and occasionally feldspar, while the diabases are more commonly aphanitic. Structures resembling amygdules and containing a zeolite, or more rarely quartz, are abundant in many of the dikes. No opportunity was found for studying the field relation of the two rock types to each other, but because of their many characters in common they are believed by the writer to be essentially contemporaneous and probably comagmatic.

The age of these dikes can not be accurately determined in the Bridgewater-Plymouth area, but from the fact that they are apparently unaffected by dynamic metamorphism, it is probable

that they were unconsolidated until after the major movements of the Appalachian Revolution and in this respect are like the albite granite of the district. Camptonite and diabase in close association have been described from many localities in northern New England and southern Quebec,[1] often in undoubted genetic connection with intrusive stocks of alkaline rocks, such as those at Mount Ascutney and Cuttingsville in the vicinity of Bridgewater and Plymouth, Braintree in north central Vermont or Red Hill in New Hampshire. From the best evidence, particularly at Cuttingsville and Mount Ascutney, the camptonite represents the last phase of intrusion and is at least as young as post-Carboniferous. The diabase dikes have often been referred to the Triassic from their superficial resemblance to the dikes of that age in the Connecticut Valley, but no direct evidence can be offered in proof of this hypothesis and the closest limitation which can be placed on their age is post-Carboniferous and pre-Cretaceous.

An average camptonite dike is exposed beside the Bridgewater-Rutland highway two miles east of West Bridgewater and a few yards north of the Riverside School, in Bridgewater. This dike is about eighteen inches wide and is oriented N 70° E. The rock is porphyritic with phenocrysts of black hornblende, up to 1.0 cm. in length, in a dense, black, aphanitic matrix. The material weathers with difficulty to a light rusty brown, and is quite fresh a centimeter below the surface. In thin section the rock shows barkevekite, altered olivine, and abundant colorless pyroxene as large crystals in a ground mass of smaller crystals of plagioclase (calcic andesine), pyroxene and magnetite. The barkevekite is less abundant and the pyroxene (aegirite-augite) more abundant than in the most typical camptonites and this rock is considered to be closer in composition to the augite camptonite described by Kemp (1893, preceding citation) from the Lake Champlain district. The most striking difference between this and the typical camptonites is the lack of *small* barkevekite crystals in the ground mass.

[1] Hawes, G. W., "Type locality for Camptonite," Am. Jour. Sc. No. 3, Vol. XVII, 1879, p. 14.
Kemp, J. F. and Marsters, V. F., Amer. Geol., Vol. IV, 1889, p. 97.
Nason, F. L., Amer. Jour. Sc. No. 3, Vol. XXXVIII, 1889, p. 229.
Kemp, J. F., Amer. Geol., Vol. V, 1890, p. 127.
Kemp, J. F. and Marsters, V. F., U. S. G. S. Bull. 107, 1893.
Marsters, V. F., Amer. Geol., Vol. XV, 1895, pp. 368-371.
Marsters, V. F., Amer. Geol., Vol. XVI, 1895, pp. 25-39.
Lord, E. C. E., Amer. Geol., Vol. XXII, 1898, pp. 342-346.
Washington, H. S., Jour. Geol., Vol. VII, 1899, p. 284.
Daly, R. A., U. S. G. S. Bull. 209, 1903, pp. 86-87.
Emerson, B. K., U. S. G. S. Bull. 597, 1917, pp. 205-206.
Eggleston, J. W., Rpt. Vermont State Geologist, 1917-18, p. 189.
Richardson, C. H., Rpt. Vermont State Geologist, 1923-24, p. 98.
Bancroft, J. A. and Howard, W. V., Trans. Roy. Soc. Can. No. 3, Vol. XVII, 1923, p. 17.

On the steep west slope of Soltudus Mountain, in southern Plymouth, an acid camptonite dike ten feet wide outcrops with an east-west trend. This dike is light grey with black phenocrysts in the central portion, but grades into dense black aphanitic rock along the walls. The central portion is unique from that of other dikes in that it contains rounded, amydule-like bodies of glassy quartz up to 1.0 cm. in diameter. The rock contains the following minerals: barkevekite, abundant as prisms and basal sections with inclusions of magnetite and apatite; pyroxene (aegirite-augite) as occasional subhedral phenocrysts; plagioclase, much altered and of indeterminate composition, forming the major portion of the ground mass of the rock; apatite, common as basal sections and as long prisms up to 1.5 mm. in length; magnetite, abundant as small anhedral grains; and sericite and calcite, present as alteration products of the feldspar. The marginal portion of the dike is much more aphanitic than the central portion, but contains the same essential minerals. The barkevekite is much more abundant and the plagioclase somewhat less altered. Occasional tiny areas of indeterminate isotropic material are present interstitial to the feldspar.

Three other dikes in Bridgewater, one in northeastern Bridgewater Hollow, a second on Southgate Mountain northeast of Bridgewater Corners, and a third in the Ottauquechee valley about two miles west of Bridgewater Corners, all showed the same composition and texture as the marginal portion of the dike described above. Each contained tiny patches of a cloudy, white, isotropic mineral of low index of refraction, probably analcite; and each was characterized by abundant small crystals of barkevekite, with some augite. A camptonitic dike rock from near the Bridgewater Hill road, one and a quarter miles east of West Bridgewater, was unusual in that it contained numerous small, white, amygdule-like bodies made up of a zeolite, which on analysis yielded: SiO_2 40.33, Al_2O_3 31.24, CaO 13.30, H_2O 12.59 and Na_2O 2.54 by difference.[1] This analysis is of necessity approximate because of the extremely small quantity of material available for examination, but nevertheless fixes the identity of the mineral as *thomsonite*.

Two very typical diabase dikes outcrop on the hillside north of Bridgewater Village. The first strikes with slight variations, N 12° E and can be followed for several hundred feet up the hillside between the elevations of 1,200 feet and 1,450 feet. The second outcrops at an elevation of 1,700 feet, due north of the village, and strikes N 40° E. Both dikes vary in width along the strike, but the first is about four feet wide and the latter six. Each is slightly porphyritic, bearing small crystals of black pyroxene even

[1] Analysis by Dr. A. H. Phillips, Princeton University, 1927.

in the marginal phases, but the ground mass is quite aphanitic and uniformly dark grey. The following minerals are present, as determined in thin sections: plagioclase, approximately calcic labradorite, abundant as small interlocking laths producing the typical diabasic texture; augite, in crystals of two generations, the first as large (2.0 mm.) phenocrysts with alteration rims, and the second as small grains interstitial to the feldspar; magnetite, abundant as small anhedral grains also interstitial to the plagioclase; and calcite common as small grains throughout the rock. The marginal phases of the dikes are essentially the same as the central portions except that the texture of the ground mass is much finer and two distinct generations of plagioclase are in evidence, the first as laths up to a millimeter in length and the second as a mesh of tiny needles surrounding the larger crystals. It is inferred from the above that some augite and plagioclase had crystallized from the intruded liquid before its introduction to its final resting place and the subsequent crystallization of the finer-grained ground mass.

Other diabase dikes from Bridgewater show the same essential characteristics as those described above.

STRUCTURAL GEOLOGY AND METAMORPHISM

STRUCTURAL GEOLOGY

The general structure of the sedimentary formations, younger than the pre-Cambrian, in Bridgewater and Plymouth, is a homocline with superimposed isoclinal folding on a small scale. All dips recorded in the area are to the east, with the exception of a few on the limbs of small isoclinal folds in the upper Missisquoi and the Ordovician rocks. The strike of all the formations is usually within a few degrees of north, but is very variable locally so that in a distance of a few yards along the strike it may vary ten degrees east to ten degrees west, or even more.

Practically no reliable data on structure can be obtained from the pre-Cambrian rocks because bedding planes have become obliterated during the process of metamorphism, and crumpling is often intense. Observations made by Whittle[1] on the Mendon Series have led him to postulate a series of sharp, compressed folds striking approximately north and overturned to the west so that the induced schistosity and stratification dip eastward. This theory is not contradicted by any observation made in the Plymouth area, but on the other hand is not definitely confirmed. The Bethel and Pinney Hollow Schists, because of their lithological uniformity throughout, give no clues to structure except along their margins. The other formations, however, contain

[1] Whittle, C. L., Amer. Jour. Sc., Vol. XLVII, May, 1894, p. 354.

beds of sufficiently contrasting lithology to furnish unquestionable dips and strikes.

Conditions are such as to lead one to suspect isoclinal folding uniformly overturned from east to west throughout the entire section, but a close examination of the strata with this theory in mind showed no unquestioned repetition of beds except in one instance which is interpreted as a possible northward pitching anticline and syncline involving the base of the Pinney Hollow Schist and the underlying beds, just north of Plymouth Notch. Any isoclinal folding must then, with the exception noted above, be on a very small scale and in other words be intraformational rather than interformational. Most of the recognized folds range in size from less than a foot to about twenty-five feet in maximum width and have undoubtedly operated to thicken the section considerably. In several cases small, local overthrusts are developed in the non-competent Pinney Hollow Schist where small folds have been stretched to the breaking point. These faults all dip east at about forty-five degrees or at approximately the angle of the bedding. No major overthrusting was detected.

Igneous intrusions are much more common in the deformed eastern zone, particularly in the Missisquoi formation, and are practically absent from the western, older Cambrian section.

Joints are abundant in all the more massive formations of the section, particularly the Bethel and Pinney Hollow Schists and the "older Cambrian" rocks. Two distinct systems of joints are in evidence: the first approximately north and south parallel with the strike of the strata and dipping west at right angles to their dip, and the second oriented vertically and at right angles to the strike of the rocks.

METAMORPHISM

The intensity of metamorphism of the rocks in Bridgewater and Plymouth is in marked proportion to the complexity of structure. This is particularly true in the Cambrian rocks in which two distinct mineral facies zones are evident. The younger sedimentary formations, *viz.*, the Missisquoi and Bethel Schists, are characterized by an abundance of garnet (almandite?) and biotite with some amphibole, dependent upon the original bulk chemical composition of the rock. The metamorphosed igneous rocks of the same zone are characterized by uralite (pargasite), epidote, and relic plagioclase and pyroxene in the dioritic type or by talc, ankerite and rarely tremolite in the very basic type. Sericite, albite, quartz, and magnetite are present in this zone as well as the next, so that they may be considered as persistent minerals.

In the western or older Cambrian zone the mineral assemblage is characterized by chlorite, sericite, albite, dolomite and

quartz. There is a marked absence of biotite and garnet in this zone, in spite of the fact that the original composition of some of the rocks in both zones was undoubtedly very similar, and hence similar groups of minerals might be expected after metamorphism. A comparison of the Pinney Hollow Schist of the lower zone with the Bethel Schist of the upper, affords an excellent example of the variant effects of metamorphism on rocks which were primarily similar. The Bethel Schist includes local areas in which the garnet content is at least ten per cent and scattered garnets are common in the entire formation, while in the Pinney Hollow Schist garnets and similar minerals are rare and poorly developed at best.

Coincident with the variation in minerals in the two zones, the rock structures are in contrast. In the upper zone isoclinal folding on a small scale is common. The rocks have quite evidently been subjected to much stress and have furthermore yielded freely, while in the lower zone folding is much less in evidence and the stress applied was absorbed by recrystallization and slight movements more or less in the plane of bedding, rather than by strong deformation.

The general setting described above suggests to the writer that there are here represented two mineral facies quite in agreement with those suggested by Eskola[1] in his paper on "The Mineral Facies of Rocks." The Pinney Hollow Schist and older rocks agree in detail with Eskola's "green schist facies" in their mineral composition. The Bethel and Missisquoi Schists on the other hand, have the characteristic mineral assemblage of his "amphibolite facies."

It is clear that equilibrium was not reached during the metamorphism of the eastern zone since some minerals inconsistent with the amphibolite facies, notably epidote, talc and ankerite, are present in the associated metamorphosed intrusives. These are, in this case, considered to be relic minerals of a metamorphic facies of lower grade. The fact that they are confined to the intrusive bodies of the zone suggests that slightly different factors were involved in the metamorphism of these bodies than in the surrounding country rock.

GEOLOGICAL HISTORY OF THE REGION

The geological history of the Plymouth-Bridgewater area, in itself, is indicative in a general way of the history of the entire eastern Green Mountain belt. It is necessary, however, to consider the geological record of nearby localities in order to include a more complete succession of events than is given only within the original area.

[1] Eskola, P., Norsk Geol. Tidsskrift, Vol. VI, 1920-21, pp. 143-194.

The pre-Cambrian history of the Green Mountains has never been established in detail, but many of the principal events have been recognized. Two distinct periods of sedimentation are shown in the two series of metamorphosed sediments, the Mount Holly and Mendon Series, described by Whittle. As mentioned above, both these series were referred to the Algonkian (as of 1889). According to present nomenclature the older series is most probably Archean, although the younger may still be regarded as Algonkian.

The oldest rocks in Plymouth, as indicated by the field relations, are the dolomites, quartzites, and chlorite schists of the Mount Holly Series. These may with reasonable certainty be considered as representing a time of marine sedimentation, although the complexity of structure in the region renders impossible the establishment of a definite stratigraphic section, and consequently nothing can be postulated concerning the details of the history of that particular time. Associated with the sedimentary rocks are bodies of amphibolite, particularly well exposed in Mount Holly township, adjoining Plymouth on the southwest. Some of these amphibolites may represent extrusives, but others are clearly intrusive into the schists and gneisses. Granite gneiss is particularly abundant and is, for the most part, clearly intrusive into the Mount Holly Series, as is shown on Salt Ash Mountain, in Plymouth, where much of the mountain is made up of coarse granite gneiss showing *lit par lit* injection into chloritic and hornblendic schists.

A period of erosion intervened between the formation of the Mount Holly Series and the overlying Mendon group. Whittle mentions several occurrences of metamorphosed conglomerate at the base of the Mendon, although these were not found in the Plymouth area, the demarkation between the gneiss intruding the Mount Holly and the overlying Mendon is apparent. It is clear that a period of acute disturbance, uplift and erosion, followed or accompanied the intrusion of igneous rocks into the older pre-Cambrian and that later subsidence paved the way for the deposition of the Mendon Series, made up originally of sandstones, shales, and limestone. The difference in degree of complexity of structure between the two series indicates a probable disturbance of orogenic magnitude. Whittle emphasizes the importance of the amphibolites common in the town of Mount Holly, and interprets these as basalt *extrusives* which are present in the lower series but not in the Mendon Series, thus inferring a period of disturbance of the lower series which did not affect the upper one. In turn the structure of the Mendon Series, shown to be isoclines overturned from east to west to produce a dip of about twenty-five degrees east, is much more complex than in the overlying (Cambrian) rocks. The period of disturbances following

the deposition and consolidation of the Mendon Series was evidently characterized by compression from the east jamming the strata against the resistant Archean rocks on the west, and doubtless forming schists and quartzites in the process.

The base of the section which is interpreted as Cambrian by the writer, is marked by the white, somewhat pebbly quartzite and dolomite, but not by a distinct conglomerate. It is evident from the shape of the best-preserved pebbles that active erosion, either fluvial or marine, was going on near by during the formation of these beds. The source of the sand and pebbles is probably to be found in the pre-Cambrian rocks to the west, especially since no probable source is known to be present to the eastward. There is thus an indication of the existence of a land mass in the position of the present central Green Mountain belt at the beginning of Cambrian sedimentation. This view is further substantiated by the presence of numerous large pebbles of gneiss and quartzite in somewhat higher members of the lower Cambrian group.

Considerable fluctuation of conditions is indicated by the variety of lithologic types in the older Cambrian rocks. This is interpreted as correlative to a near-shore environment in this case. It is probable that the dolomites, which are locally variable, represent deposition by chemical precipitation in lagoons or other isolated bodies of water along a shore zone, especially since the pebbles of blue vein-quartz, quartzite and orthoclase feldspar, found in close association, were clearly derived from a nearby land mass. Following the deposition of the sandstones, arkose and dolomite of the basal beds, came black shale followed again by fine sandstones and dolomite in northern Plymouth, and by conglomerate and dolomite in southern Plymouth. The conglomerate is interpreted as a fluvial deposit, probably a delta deposit, from its obviously local distribution along the strike. The large angular blocks of quartzite at the base of the formation offer further indication of a strictly local origin.

The formation overlying the conglomerate-sandstone-dolomite horizon was a laminated shaly sandstone, indicating by the change in size of clastic materials a probable change in conditions of sedimentation from near-shore to relatively off-shore deposition. There was fluctuation between the formation of small beds of pure sandstone and black shale, with all intermediate gradations.

Upon the older Cambrian group, the Pinney Hollow formation was deposited as a thick, relatively uniform series of shale beds. The environment and supply of material during this time was apparently constant and the material may have been derived from a more distant source than that of the older formations, since it was obviously better sorted and of finer grain, or else the parent land mass was by this time reduced to a low flat plain and the sluggish streams flowing from it carried only fine materials. No carbon is noticeable in the Pinney Hollow formation as contrasted with the overlying Ottauquechee group, which was a black shale, and at present contains abundant disseminated carbon. A change in the composition of materials supplied is thus indicated, and the sandstones associated with the shale are a further proof of a change in environment. The black shale, as such, cannot be said to require any single set of conditions for its formation, but in this case, because of the associated sandstone, probably formed in relatively shallow water in an embayment between the present Green Mountain mass on the west, and some other land area on the east side of the present Connecticut River drainage area.

At the close of the time of deposition of the Ottauquechee black shale, conditions apparently reverted to those under which the Pinney Hollow formation was laid down, and the deposition of the Bethel formation took place. The oscillation between black shale and non-carbonaceous shale, at the base of the Bethel, indicates a general similarity of conditions of deposition of these two rocks, although in the former organic matter was abundant, and in the latter was practically absent. The uniformity of the Bethel formation indicates, again, stability of conditions of sedimentation over a considerable period of time, terminated by an abrupt change at the beginning of deposition of the Missisquoi Group. The latter was predominantly a thin-bedded sandstone with numerous shaly beds at first, with increasing proportion of quartz sand in the upper layers.

Some evidence of an unconformity between the Bethel and Missisquoi formations is indicated, but not proved, by the fact that several distinctive beds in the Missisquoi of northern Bridgewater seem to end against the Bethel Schist as they are traced southward. This would indicate a progressive overlap from north to south, but in view of the paucity of evidence, should be regarded as no more than a suggestion at present.

The evidence concerning the history of this region between the late Cambrian and early Ordovician times is of a very positive nature. The Irasburg conglomerate found at the base of the Ordovician in north central Vermont indicates a period of active erosion of the Cambrian rocks, prior to the deposition of the early Ordovician shales and limestones. There is no positive evidence in the Bridgewater area of folding of the Cambrian rocks prior to the Ordovician so that any movements were probably of the nature of simple uplifts. The amphibolites which are common as intrusives into the Missisquoi do not intrude the Ordovician rocks at any locality studied, but on the other hand no outcrop was noted in which the amphibolite could be interpreted as forming part of the erosion surface on top of the Missisquoi. The exact age of the intrusion of the amphibolite is thus left in doubt, but it may be provisionally placed as late Cambrian until further evidence is found of their intrusion into younger formations. Similarly the steatite bodies representing intrusions into the various Cambrian rocks, may be dated as late Cambrian or younger. In view of the well-recognized association of periods of intrusion with mountain building, it is quite possible that the intrusion of the amphibolite bodies is to be connected with the post-Ordovician movements in this area, but judged from their degree of metamorphism they are older than the late Paleozoic movements and the unmetamorphosed granitic intrusives associated with the latter.

The Ordovician limestone and phyllite represent deposits of shale and sandy limestone formed in a marine trough or estuary extending along the east side of the Green Mountains from Quebec into Massachusetts. No younger Paleozoic formations, of undisputed age, have been found in Vermont, although a small area of Silurian is known in the Ammonoosuc[1] district of western New Hampshire and a small area of Devonian outcrops on the shore of Lake Memphremagog[2] in Quebec, near the Vermont line. The presence of these eroded remnants of marine Silurian and Devonian formations suggest that much of eastern Vermont was once covered by them. Unfortunately, the relationship between the structure of the Ordovician rocks and that of the younger strata has nowhere been observed and consequently no definite proof can be offered concerning the widely postulated orogenic movement at the close of the Ordovician. Clark[3] in his paper on the Taconic Revolution summarizes this problem in its application to New England, and concludes that the evidence in favor of a *widespread* Taconic Revolution is negligible. It is thus questionable whether a disturbance at the close of the Ordovician can be postulated for the Green Mountain region.

Whether or not the Taconic Revolution in part contributed to the metamorphism of the rocks in the Plymouth and Bridgewater district, the Appalachian Revolution of the late Paleozoic was obviously a large factor. Lateral pressure from the east was effective in compressing the Ordovician and youngest Cambrian rocks into isoclinal folds. This effect dies away from east to west and the older strata of the section were not affected by strong folding, although they were recrystallized and rendered schistose. It is very probable that a range of mountains of considerable height occupied the present site of the Green Mountains and adjoining regions, in the late Paleozoic. Into the rocks of this

[1] Lahee, F. H., Amer. Jour. Sc. No. 4, Vol. XXXVI, pp. 231-251.
[2] Ells, R. W., Ann. Rpt. Geol. Sur. Can., 1894, Part J, map.
[3] Clark, T. H., Bost. Soc. Nat. Hist. Proc. No. 3, Vol. XXXVI, 1921, pp. 134-163.

range the present unmetamorphosed granites of the area were intruded. In view of the fact that the granite of Plymouth shows no gneissic structure, the writer believes that the date of intrusion and cooling must necessarily be placed during the last part of the Appalachian Revolution in this region. The basic dikes comprising the youngest lithified rocks of the area are probably either comagmatic with the granites and represent the last phases of intrusion of a common magna, or are to be correlated with the diabase intrusions of early Mesozoic age in the lower Connecticut valley.

During the Mesozoic, the Green Mountain region was probably undergoing active erosion and becoming worn down to the ultimate peneplain and low monadnocks of the Cretaceous. At the end of the Mesozoic the above peneplain was uplifted, and stream erosion during the Tertiary established the essential features of the present topography. At least one area of deposits of Tertiary age is known in Vermont, at Brandon, but no evidence of deposits of this age is found in Plymouth or Bridgewater. It has been suggested that the earthy iron ores found at Tyson are to be referred to this period, but no paleontological evidence was ever found there to the knowledge of the writer.

During the Pleistocene, the region was alternately covered and exposed by continental glaciers. Their chief effect was to modify the old Tertiary topography and to deposit glacial till and sorted sand and gravel in the valleys. Some modifications in drainage were effected during the Pleistocene, so that post-glacial streams have in many cases cut steep youthful gorges in new channels.

CORRELATION

The correlation of the section in the Bridgewater-Plymouth area with those of other nearby regions is rendered difficult by the total lack of recognizable fossils in any of the formations. It is thus impossible to assign an absolute age to any of the beds and correlation must be carried on through a comparison with the beds in other areas in view of their lithology and stratigraphic succession. The establishment of the continuity of formations by tracing them along the line of strike is obviously the best method of correlating separate sections of the type under consideration. Sufficient data for the application of this method are, however, not available for more than a limited correlation with other parts of central Vermont, eastern Quebec, or western Massachusetts. A comparison with formations in western Vermont, on the opposite side of the Green Mountains, is problematical at best.

The formations in Plymouth and Bridgewater have long been recognized as a part of a belt of related formations extending along the eastern side of the Green Mountains from Canada to

Massachusetts, although the individual members of the group have been subjected to but little study. The accompanying table (page 58) indicates the probable relation of the Plymouth-Bridgewater section to those to the north and south and includes a comparison of the names given to these formations by different writers. No attempt has been made in this table to express the relation between the formations of the area studied and those on the west side of the Green Mountains. Many authors, notably Pumpelly, Wolff, Dale, and Emerson in Massachusetts, E. Hitchcock, T. Sterry Hunt, and Whittle in Vermont and Ells in Quebec, have attempted such a correlation and their conclusions will be considered below.

In the eastern Green Mountain belt the Ordovician limestone and phyllite constitute the most continuous and best-defined formation and below it the difficulty of correlation increases in proportion to the age of the formations compared, as a general rule. The pre-Cambrian rocks of the Green Mountain *axis* are, however, commonly considered to form a continuous, well-defined belt of outcrop from the southern border of Vermont nearly to the Chaudiere River in Quebec. The relation between these rocks and the pre-Cambrian of the Adirondacks, or of eastern New England, is unknown although C. H. Hitchcock[1] attempted such a correlation on a purely lithologic basis. This correlation on the present knowledge of New England geology can be regarded as little more than highly speculative. The Mendon Series was found by Whittle to overlie the central gneiss on either side of the Green Mountain axis and this constitutes the most certain proof of the anticlinal structure of the range, and the only evidence for the correlation of separate areas within the pre-Cambrian belt.

The only rock type of the older Cambrian for which it is possible to suggest a correlation is the dolomite of Plymouth. This dolomite agrees in stratigraphic position and association with those described by Dale[2] in Jamaica and Ludlow to the south and Rochester and Hancock to the north. Hitchcock and Hager have in addition mentioned dolomites in Andover, Sherburne and Granville in this same general belt, bordering the pre-Cambrian on the east. From the fact that the older Cambrian on the western side of the Green Mountains contains pink dolomite and quartzite in close association, it is very suggestive that the pink dolomite and white quartzite of Plymouth, in the same stratigraphic position, may form its counterpart on the east. This point was one of Hitchcock's major arguments for the anticlinal structure of the mountain range, but further evidence, particularly paleontological evidence, will be required to prove the point. The other older Cambrian formations are not sufficiently

[1] Hitchcock, C. H., Proc. A. A. A. Sc., Vol. III, September, 1884 (abst.).
[2] Dale, T. N., U. S. G. S. Bull. 589, 1915.

Correlation Table

1927	1861	1898-1917	1920	1908	1894	1914
E. L. Perry	E. Hitchcock and A. Hager	B. K. Emerson	C. H. Richardson	C. H. Richardson	R. W. Ells	T. N. Dale
Bridgewater and Plymouth, Vt.	Vermont	Western Mass.	Braintree, Vt.	Northern Vermont	Montreal Map Area, P. Q.	Eastern Vermont
Waits River Limestone	Calciferous Mica Schist (in part)	Conway Schists	Waits River Limestone	Waits River Limestone (Washington Limestone)	Farnam Black Shales and Limestone	
Randolph Phyllite	Calciferous Mica Schist (in part)	Goshen Schists	Memphremagog Group (in part)	Memphremagog Group (in part)	Cambro-Silurian Slates of Memphremagog	
Missisquoi Group	Talcose Schist (in part) and Gneiss	Hawley Schist (?)	Missisquoi Group	Upper Cambrian Sericite Schist and Quartzite	"Cambrian Area east of Sutton Mountain"	
Bethel Schist	Talcose Schist (in part)	Savoy Schist (?)	Hydromica Schist	Pyritiferous Mica Schist (?)		
Ottauquechee Group	Talcose Schist (in part) "Clay Slate"	(Chester Amphibolite) (??)				
Pinney Hollow Schist	Talcose Schist (in part)	Rowe Schist				
Plymouth Dolomites	Dolomitic and Siliceous Limestones in the Talcose Schist					Marbles of Ludlow, Jamaica, Rochester, Hancock and Granville, Vt.
Albitic Schist	Talcose Schist (in part)	(Hoosac Schist?)				"Muscovite-biotite albite schist" of Jamaica, Vt. (?)

distinctive lithologically to serve as units for correlation; they are, however, included in the formation mapped by Hitchcock, in 1861, as the "talcose schist" and probably constitute the basal group of that series of rocks extending along the eastern side of the Green Mountains. There is at present no basis for judging the continuity of the lithology of these rocks as they are exposed in Plymouth.

The Pinney Hollow, Ottauquechee, and Bethel Schists are, like the older Cambrian rocks, included in Hitchcock's "talcose schist" and comprise the major part of that formation. The Ottauquechee was recognized as distinctive, however, and was called the "clay slate in the talcose schist." It is mapped as extending about twenty miles north of Bridgewater and also in a long line of outcrop in the northern part of the state. No equivalent for this phyllite can be found in the descriptions of rocks from the southern part of the state. The Pinney Hollow and Bethel Schists are believed to correspond respectively to the Rowe and Savoy Schists of the Massachusetts section[1] and hence to the upper Readsboro and Halifax schists in the adjoining section in southern Vermont, as described by Hubbard.[2] The lithology and stratigraphic sequence of the formations in the last-named areas is in good general agreement with those in the Bridgewater-Plymouth region and according to Hitchcock's map there is a continuity of formations in between. The Bethel Schist has been mapped, in its northward continuation from Bethel, as the "Hydromica Schist" in several reports by C. H. Richardson. It is probable that the "pyritiferous mica schist" of Troy, Vermont, described by the same author in 1908, is also to be correlated with the Bethel Schist since it has the same essential lithology and the correct stratigraphic position with regard to the more definite overlying formations. In comparing the sections on either side of the Green Mountains it is noticeable that corresponding with the great thicknesses of shale represented by the combined Pinney Hollow, Ottauquechee, and Bethel Schists on the east side, that there is a comparable thickness of Upper Cambrian slates and shales on the western side. Kieth,[3] however, concludes from his studies in northwestern Vermont ". . . . that there is only a small extension of the Ordovician and also of the Upper Cambrian eastward from the Green Mountains," so that the above comparison can be regarded as no more than a suggestion to be kept in mind during future work. The exact equivalent of the Pinney Hollow, Ottauquechee, and Bethel Schists in Quebec is unknown, but from maps at present available they may well correspond to a part of the Sillery formation.

[1] Emerson, B. K., U. S. G. S. Bull. 597, 1917, pp. 41-42 and map.
[2] Hubbard, G. H., Rpt. Vermont State Geologist, 1923-24, p. 291.
[3] Kieth, A., Rpt. Vermont State Geologist, 1923-24, p. 132.

The Missisquoi Group offers less difficulty of correlation than do the underlying rocks, since they have been traced in a continuous belt of outcrop from the northern Vermont border to the area at present under consideration. They were up to 1918 referred to as the "Upper Cambrian sericite schist and quartzite" by Dr. Richardson, who has done most of the work of mapping this formation. The Missisquoi most probably corresponds to the upper part of the Sillery in Quebec. This idea was suggested as early as 1867 by C. H. Hitchcock[1] and is implied by Ells (1894) in his map of the Eastern Townships of Quebec, as found by comparing the latter with the map of some of the border towns in Vermont, published by Richardson in 1908, when the first work was done in separating the Missisquoi from the other associated formations. The position of the extension of the Missisquoi southward from Plymouth is uncertain, since none of the formations in the Massachusetts section is directly comparable in lithology. The Hawley Schist of the latter section bears, however, the same stratigraphic relation to the well-defined, overlying, Ordovician limestone as does the Missisquoi farther north, and is the most probable equivalent. The corresponding formation in southern Vermont has not been studied as yet.

The Waits River limestone and associated phyllite constitute the most widespread and best-known formation in eastern Vermont. The limestone and phyllite are the exact equivalent of Hitchcock's "Calciferous Mica-schist" of the older literature and have been traced as such from the Canadian border southward to the Massachusetts boundary, where they have been described by Emerson as the Conway and Goshen Schists. The writer has visited outcrops of the latter formations in northern Massachusetts and southern Vermont and found them to be lithologically identical with the Waits River and Randolph formations in north central Vermont. C. H. Hitchcock has used the name Conway Schist[2] in his study of the geology of the Hanover Quadrangle for the Waits River formation in the eastern part of its belt of outcrop. Richardson has traced the western border of the belt from the Canadian line southward as far as Reading, Vermont. The extension of the formation from the international boundary into Quebec has been mapped by Ellis[3] and is called the "blackish or dark-grey limestone of Cambro-Silurian age" in his report on southeastern Quebec, and the "Farnam black shales and limestone" in his later report on the Montreal map area.[4] The outcrop belt of the formation trends northeast from the border and extends at least across the Chaudiere River to the north.

[1] Hitchcock, C. H., Proc. A. A. A. Sc., 1866-67, pp. 120-122.
[2] Hitchcock, C. H., Rpt. Vermont State Geologist, 1911-12, p. 101.
[3] Ells, R. W., Geol. Sur. Can. Ann. Rpt., 1886, Part J, map.
[4] Also the above, 1894, Part J, map.

The Randolph Phyllite is considered by Richardson, as indicated in several of his reports, to belong to the Memphremagog group of slates and phyllites which occurs in and near the base of the Waits River Limestone in the northern section. This would imply an identity, in part at least, with the Magog shales of the Canadian section and which are known to be of middle Ordovician age from an extensive graptolite fauna found in them.

ECONOMIC GEOLOGY

DOLOMITE

Most of the dolomite beds of Plymouth and Bridgewater have at some time been used as a source of quick lime. Abandoned kilns are common in the vicinity of the dolomite outcrops and at least two kilns have been in recent use (1925). With few exceptions the lime-producing industry has never been systematically or continuously pursued in Plymouth, but has instead been a part-time occupation of men normally engaged in farming.

Much of the dolomite is too impure for making lime without some preliminary hand picking to remove quartz or micaceous layers, but in some parts of the beds the dolomite is quite pure and can be roasted directly as it comes from the quarry. The most troublesome impurity is quartz, present both as small veinlets and as small grains in the sandy phases of the formations. This quartz acts as a flux and causes sintering of the charge during the roasting process. Other impurities often present are iron and manganese producing the pink and red coloration in the lower dolomite, and carbonaceous matter coloring the dark phases of the upper beds. These do not seem to produce a markedly undesirable effect on the roasted product. The best dolomite for roasting is that in the upper bed a short distance north of Plymouth Notch, and in the lower bed north of Plymouth Union.

The kilns used in producing quick lime are all of the periodic type, six to ten feet in internal diameter, and about ten feet in height. All the kilns are built on hillsides so that they are readily charged from above and the "burned" lime drawn off from an opening at the base. Wood is used as a fuel. The lime produced is considered to be of excellent quality, but the cost of transporting the finished product to Ludlow does not permit of competition with other lime plants more favorably situated with respect to a railroad.

The dolomite from the small quarry near the head of Amherst Lake in southern Plymouth was used to a limited extent as a fancy marble for interior construction. The particular bed used for this purpose is metamorphosed intraformational conglomerate (or breccia) composed of rounded or subangular phenoclasts of white dolomite in a matrix of carbonaceous, dark-grey dolomite. The bed is about a yard thick and is interstratified between beds of white dolomite. It is strongly jointed and consequently the proportion of waste in quarrying was too high for practical operation.

GOLD DEPOSITS

Gold is known to be widely distributed in Vermont, but it is rarely to be found in sufficient concentration to prove of commercial value. The town of Plymouth is exceptional in that it is the only town in the state in which gold deposits have yielded a profitable return on the time and energy expended in working them, but then only in a few instances. The deposits are of two types, quartz veins and placers, but only the latter have been worked at a profit.

Gold was first discovered in this district in 1851, in the town of Bridgewater, by Mathew Kennedy.[1] The exact location of the discovery vein is unknown, but was about one mile west of Bridgewater Center (Briggs) in Dailey Hollow and probably at about the top of the Bethel Schist (see map). The property later came to be known as the "Taggart vein" and was worked intermittently for a few years about 1859, but apparently much more money was expended on metallurgical machinery than was ever regained in the value of metal extracted. The gold was evidently very unevenly distributed in the vein and, although some pockets may have been as rich as is claimed, much of the ore was evidently low in metallic content as is shown by the following assay quoted by Dr. G. O. Smith[2]: gold, none; silver, 1.27 oz.; copper, 6.19 oz.; and lead, 6.26 oz. The vein was claimed to have yielded 18.7 oz. of gold per ton on ten tons treated. Other veins were prospected on the Ottauquechee River near Bridgewater Corners and also in Dailey Hollow one and a half miles due south of Chatauguay. The latter property was connected by road over the hill to an extensive mill at Chatauguay, but as far as could be learned by the writer, very little ore was treated and the whole project was a fraudulent scheme. In Plymouth, a mine was opened on a quartz vein intruding the Pinney Hollow Schist beside the Reading Pond Brook, about one and a half miles northeast of Tyson. This is now known locally as Foxes' Mine, from the name of its last operator, but was originally operated by the Rooks Mining Co. It seems never to have yielded a profit on the investment, and although native gold is unquestionably present in the mine, it is probably present in such small quantities in the aggregate as to make mining impractical. The mine is at present in such a state of disrepair that the exploration of it is impossible, but from surface indications and exposures in two raises which reach the surface, the mine consists of drifts and raises along a very irregular quartz vein intruded in the plane of the schistosity of the country rock, which is here oriented N 3° W, dip 60° E. The mine is situated on a steep, southward sloping hillside, with an adit and ruins of a mill slightly above the level of the brook at the base of the hill and the upper workings, apparently a head house over a shaft, about 170 feet above the brook.

[1] Hager, A. D., *et al.*, Rpt. Vermont State Geologist, Vol. II, 1861, p. 844.

[2] Smith, G. O., U. S. G. S. Bull. 225, 1903, p. 87.

From the above it may be inferred that mining of the gold-quartz veins of the district is unprofitable, since the metallic contents are very low in total average and very irregular in distribution.

Gold in placer deposits has been known in Plymouth since about 1855, in which year prospecting is said to have yielded about $500. In the next few years gold was found in the gravels of Reading Pond Brook and its tributary Buffalo Brook, Kingdom Brook, and the streams in the vicinity of Plymouth Five Corners. At the latter locality in the years 1858 and 1859, William Hankerson is reported to have washed several hundred dollars' worth of gold from the sediment in the bottom of a mill pond and during this same time about $7,000 worth was estimated to have been washed in the entire town. These figures are unreliable at best, but perhaps give an idea as to the general magnitude of operations at that time. Since 1860 very little has been done in placer mining in Plymouth, although even at the present day some "panning" is carried on by local residents. The writer has observed the results of "panning" on Reading Pond Brook near Foxes' Mine and pieces of gold an eighth inch in diameter may be obtained from natural riffles formed by upright plates of schist in the bed of the stream. Considerable fine dust is also present with the small nuggets, but the labor involved in extracting the gold from between the plates of schist is worth more than the gold obtained. The process is hardly more than a holiday diversion at best.

The gold in the stream beds and the hillside gravels has been very probably derived from the denudation of gold-bearing quartz veins nearby. The concentration of the gold in this manner has, as seen above, produced a few deposits of commercial value, even though the original vein rocks do not constitute workable ore.

GRANITE

The granite previously described as outcropping on the south slope of Morrison Hill in Plymouth has been used to a limited extent as a stone for exterior construction, particularly in building a small church in Sherburne, near West Bridgewater. The properties of this stone are essentially the same as those of the Bethel Granite which it so closely resembles. The church mentioned above was built in 1895 and at present, thirty years later, the rock shows no sign of decomposition or discoloration, although the mortar used in setting the blocks has in many places crumbled away.

Owing to the small size of the granite body and its general inaccessibility, it is improbable that this stone will ever have more than a very local use for fence posts and the foundations of buildings.

STEATITE

The deposits of steatite or, as it is locally called, "freestone," have been described above in considerable detail and little need be said of them at this time. From an economic standpoint the steatite deposits of Plymouth and Bridgewater are concluded to be of little value because of their small size, impurity, and distance from a railroad.

IRON

During the early part of the last century an iron furnace was operated in Plymouth, at Tyson, or as the locality was then called, Tyson's Furnace, from the name of the owner, Isaac Tyson. The ore used was said to be earthy hematite derived from the weathering of limestone such as that now present in the vicinity but some siderite was also used. The latter was obtained from several small lenticular deposits in various parts of the town, near Plymouth Union and Plymouth Kingdom in particular. Very little trace of the ore bodies is now visible and a ruined wall, across the road from the schoolhouse at Tyson, is all that marks the location of the furnace. The iron deposits have no present economic value.

ROAD METAL

Gravels used locally for road building are abundant in both Bridgewater and Plymouth. The best materials are found in the valleys and are composed of water sorted kame and river terrace gravels. These deposits are of Pleistocene age and were clearly formed by streams much larger than any now present in the region. The use of these gravels is necessarily quite local, but it is because of their abundance that good roads are made possible in the district.

THE ORIGIN OF THE BENNINGTON KAOLINS

FREDERICK A. BURT

LOCATION

The area here described lies in the extreme southwestern part of Vermont and comprises parts of four townships: Shaftsbury, Bennington, Woodford, and Pownal. The whole area forms a north-south belt about twelve miles long and six wide extending along the Vermont-New York boundary on the west, and northward from the Vermont-Massachusetts line on the south. (Figure 8.)

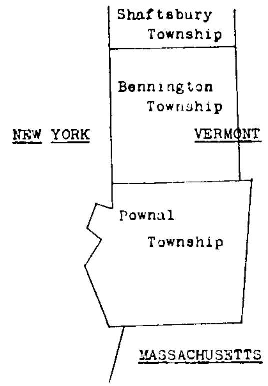

FIGURE 8.—Sketch-map of the Bennington area.

HISTORY OF DEVELOPMENT AND USE

The Bennington kaolin deposits have been known for many years. A pottery industry was first located at Bennington in 1793 when stoneware, earthenware, and firebrick were manufactured at the Norton Pottery. The clay first utilized was glacial clay from a deposit located about halfway between the village of Bennington and Kaolin Deposit No. 10 (Figure 9). It is rumored that during the last years of the existence of this pottery kaolin was taken from Deposit No. 10, but this cannot be verified.

Edward Hitchcock, following a trip through western Vermont, wrote C. B. Adams, the first Vermont State Geologist, under date of September 30, 1845, calling attention to the frequent association of quartz, sand, and kaolin on the western side of the state.

The United States Pottery, organized in 1853, operated in Bennington for a few years, manufacturing many fine wares, including Rockingham and Parian. Kaolins for this pottery were partly imported and partly taken from the deposits numbered 6, 8, 9, and 10.

In recent years the finer-grade kaolins have been worked to a small extent for paper-clays, ball-clays, and enamel ware; and the cruder grades for sagger- and fire-clays. During the past two years interest in these deposits has been greatly stimulated and

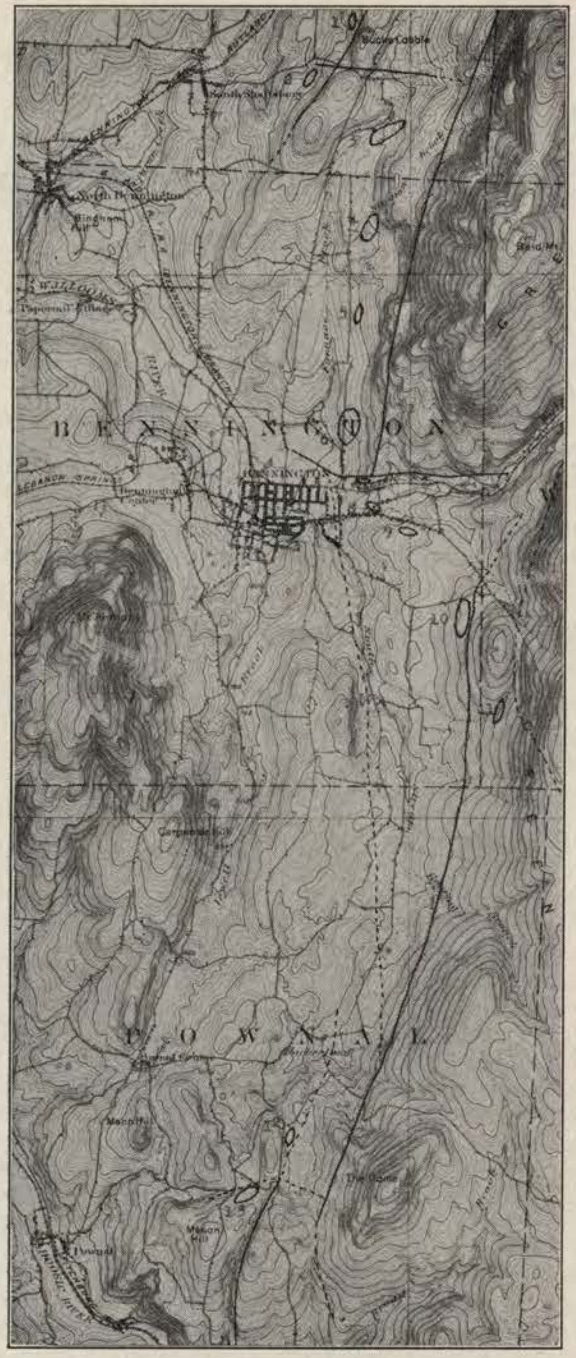

FIGURE 9.—The kaolin deposits of the area and their relations to the main faults.

much subsurface exploration carried out with a view to renewed activity in production.

PHYSIOGRAPHY AND STRUCTURAL GEOLOGY OF THE AREA

The area contains parts of three physiographic provinces. Along the eastern side lies the Green Mountain Range, which might properly be called the dissected Green Mountain Plateau. The highest of the Green Mountain peaks within the area rise to altitudes between 2700 and 2800 feet. The western edge of the plateau slopes abruptly down to an altitude of about 1100 feet. The bed rock within this province consists of pre-Cambrian gneisses and Cambrian quartzites.

Along the western side is the Taconic Range, distinctly marked in the southern part where it rises to an altitude of 2345 feet. In the northern half of the area the range is more broken and consists of scattered, lower hills. The rocks of this province consist of crystalline dolomites, limestones, and schists of Cambrian and Ordovician age.

Lying between these two ranges is the Vermont Valley which is underlaid with quartzites, dolomites, and crystalline limestones. (Figure 10.) In many places the rocks are deeply buried beneath Pleistocene drift. In its southern part this province is sharply separated from the Taconics on the west by an abrupt change in slope. In the northern part the two provinces are not so sharply separated. On the east the Vermont Valley is separated from the Green Mountains, topographically by a very abrupt change in slope, and structurally by a sharply marked belt of faulting, here designated as the Green Mountain Front Fault.

The kaolin deposits are all arranged along this fault zone, and a definite relationship seems to exist between the faults and the kaolin. A consideration of the faults, therefore, seems important in any study of the origin of the kaolin. The fault zone contains both earlier overthrusts and later normal faults. The main overthrust, according to Bain,[1] is well shown a few miles to the north of the area where the observed part of the fault plane dips to the east at an angle of less than one degree. The dip of the fault plane cannot be measured within the area here described, but there is no evidence that it departs radically from that observed farther north. The faults as shown on the accompanying map (Figure 9) are essentially as mapped by Gordon,[2] but there is a slight departure from his locations at a few points. The slight discrepancies between his interpretations of the fault

[1] George W. Bain, Geological History of the Green Mountain Front, Rpt. Vermont State Geologist, Vol. XV, 1925-26, p. 230.

[2] C. E. Gordon, Notes on the Geology in the Vicinity of Bennington, Rpt. Vermont State Geologist, Vol. IX, 1913-14, plate 68, facing p. 336.

lines and the writer's are not surprising when it is understood that most of the fault belt is heavily wooded or covered by underbrush and soil which conceals exposures, and that erosion has so far altered the topography that the present scarps cannot be depended on in locating fault lines.

THE FORMATIONS OF THE AREA WITH WHICH THE KAOLIN MAY BE GENETICALLY RELATED

A complete columnar section of the area is given in Table I. The symbols used are the same as those used in Figure 10. The formations with which the kaolin comes in contact, or with which it may have genetic relations, are the Stamford-Woodford gneisses, the Vermont formation, the lower part of the Stockbridge, and the Quaternary. These will be briefly discussed in turn.

TABLE I

Formations of the Area

Symbol	Formation	Thickness	Rock type
Q	Surficial	0–50'	Drift and soil
Ob	Berkshire	0–5000'	Graphitic and pyritic schists
ꞒOs	Stockbridge	1200 ±	Crystalline limestones and dolomites
Ꞓv	Vermont	1600 ±	Massive, brecciated, and schistose quartzites
gn	Woodford and Stamford		Quartz, feldspar, biotite, and hornblende gneisses

THE GNEISS

The gneisses of the area, commonly called Stamford gneiss, lie unconformably below the Vermont formation and form the core of the Green Mountain Range. Six of these Proterozoic

gneisses have been found in the kaolin area by the writer. One of these is the Stamford gneiss of the literature of the region. Another is probably the white gneiss of parts of Berkshire

FIGURE 10.—Diagrammatic cross-section of the Bennington area. Ob—Berkshire schist, Cos—Stockbridge limestone, Cv—Vermont quartzite, gn—Pre-Cambrian gneisses.

County, Massachusetts, the adjoining county to the south, described by Pumpelly and Wolff.[1] The identity of this gneiss with that of Pumpelly and Wolff has not been proved but the structural

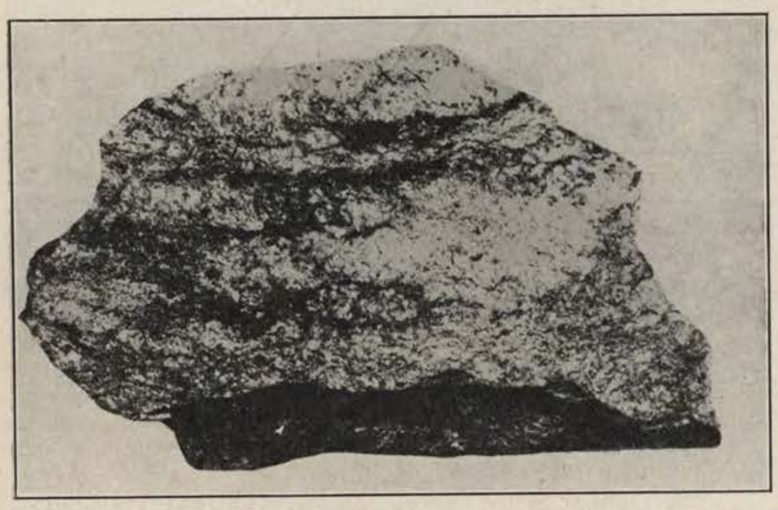

FIGURE 11.—Woodford gneiss, phase 2.

relations and the lithologic character of the two suggest their oneness. This probable white gneiss together with the four as yet undescribed and little studied gneisses will, for purposes of brevity, here be called collectively the Woodford gneisses. The

[1] Raphael Pumpelly, J. E. Wolff, and T. Nelson Dale, Geology of the Green Mountains in Massachusetts, U. S. Geol. Surv. Mon. 23, 1894, pp. 80-86.

six gneisses with which the kaolin is associated may be briefly described as follows: (1) Irregularly banded, orthoclase-quartz gneiss with considerable accessory biotite and some muscovite. (2) Irregularly banded, fine-grained gneiss predominately of pinkish feldspar with minor quartz, hornblende, and biotite. (Figure 11.) (3) An even-grained, even-banded, red orthoclase and hornblende gneiss with minor quartz. (4) Quartz-plagioclase - orthoclase - hornblende gneiss with even, conspicuously - banded layers. (Figure 12.) (5) Fine-grained, biotite gneiss with no pronounced foliation. (Figure 13.) (6) The possible white gneiss of Pumpelly and Wolff. In addition to these gneisses there are within the drift overlying the kaolin some large fragments of pegmatite which suggest the presence of pegmatite dikes, now, or formerly, in the wooded slopes above the kaolin beds.

FIGURE 12.—Woodford gneiss, phase 4.

Among the accessory minerals zircon, tourmaline, microcline, grossularite, and magnetite are common. In the thin sections which have been studied the hornblende gneiss shows a predominance of plagioclase over orthoclase, while the biotite gneiss shows a preponderance of orthoclase, but the writer would not state definitely that this relation holds throughout.

The feldspar in the exposed gneiss is all heavily kaolinized, and in some of the slides it is seen that considerable saussurite has developed. (Figure 13.)

THE VERMONT FORMATION

The Vermont Formation consists locally of 1600 feet (±) of Lower Cambrian quartzites, called by Bain,[1] the Bennington quartzite. The Cambrian age of the formation has been established by the presence within it of Olenellus,[1] and Olenellus, Nothozoe and Halithes.[2] The quartzite occurs within the area in the following phases: (1) Thick-bedded, massive quartzite, red in color and very dense. Thin sections show the rock to be almost wholly without pore space, and to consist of nearly pure quartz with small amounts of intimately mixed hematite. (2) A lower feldspathic phase in which both orthoclase and albite-oligoclase constitute conspicuous parts of the rock. In this phase the quartzite beds are interstratified with thin layers of fat, sticky kaolin. It is impossible to determine, without extensive petrographic work, whether the kaolin is secondary and represents the weathering of exceptionally feldspathic layers, or whether the clay is original, having been interstratified with the sands at the time the rock was deposited. (3) A stratigraphically higher phase of quartzite schist. This varies from a thinly laminated quartz schist which cleaves into flinty or shaly layers to a quartzite showing poor cleavage and little schistosity. Mica is a common accessory mineral and some layers are heavily pyritic. (4) A pebbly,

[1] George W. Bain, *loc. cit.* p. 222.

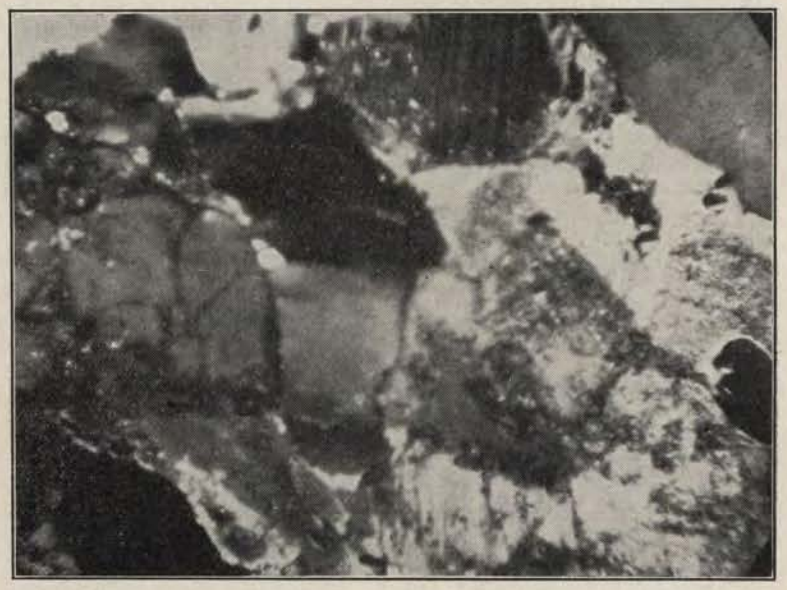

FIGURE 13.—Thin section of the Woodford gneiss (phase 5) as seen with crossed nicols.

[1] Charles D. Walcott, The Taconic System of Emmons, American Journal of Science, Series 3, Vol. XXV, 1888, p. 235.
[2] G. E. Edson, Historical Sketch of the Cambrian Age as Related to Vermont Geology, Rpt. Vermont State Geologist, Vol. V, 1905-06, p. 124.

conglomeratic phase. (5) A white, nearly pure quartz phase. Phases 2, 3, and 5, together with many veins of milky quartz, weather to a white, sugary sand.

THE BASE OF THE STOCKBRIDGE

The Stockbridge outcrops short distances west of the kaolin. Its age has been determined by the presence of Maclurea magma (Chazy),[1] and Homocrinus gracilis, Orthoceras sp., and a Rhynchonella.[2] The dolomitic phase is blue, gray, or pinkish. Under the microscope the rock is seen to consist mainly of calcite and untwinned dolomite with subordinate quartz, feldspar, and minor accessories.

The limestone is gray or bluish and thoroughly crystalline. Feldspar, quartz, and dolomite occur as minor constituents of the rock. Near the bottom of the formation dolomite, limestone, schist, and quartzite layers are interbedded.

SURFICIAL DEPOSITS

The surficial deposits range in thickness from 0 to 100 feet. They consist of Pleistocene drift, kame terraces, and lake deposits. The Recent deposits consist of lake and alluvial deposits, talus, and soil.

GEOLOGIC RELATIONS OF THE KAOLIN

The kaolin extends in a series of deposits along the Green Mountain front from south of the Vermont-Massachusetts line[3] northward to Monkton, Vermont.[4] The total distance within Vermont is about 95 miles. The kaolin is not continuous along this line, but occurs in a broken chain. Throughout the chain the deposits occur close to the Green Mountains' western front, and in the Bennington area they lie on the eastern edge of the Vermont Valley within a mile, and in all but two cases within a thousand yards, of the abrupt rise from this valley to the Green Mountain Range.

The Vermont Valley and the Green Mountains are sharply separated by a narrow complex of faults, the earliest of which are the overthrusts of the so-called Green Mountain Revolution. This overthrust complex is cut by later normal faults. The kaolin deposits of the area stand in either one or the other of the two following relationships to these faults: (1) Nine of them

[1] C. E. Gordon, Studies in the Geology of Western Vermont, Rpt. Vermont State Geologist, Vol. XII, 1919-20, p. 231.
[2] G. E. Edson, loc. cit. p. 126.
[3] W. O. Crosby, The Kaolin in Blandford, Massachusetts, Massachusetts Institute of Technology Quarterly, 1880, pp. 228-237.
[4] E. C. Jacobs, The Clay Deposits and Clay Industries of Vermont, Rpt. Vermont State Geologist, Vol. XV, 1925-26, p. 202.

(numbers 1, 2, 3, 4, 5, 6, 10, 11, and 12, see Figure 9) lie on the downthrow side of branches of the Green Mountain overthrust, and very close to it. The positions now occupied by these deposits are below the westward extension of the old overthrust plane before erosion shifted the scarps eastward. (This condition will be more fully discussed in Figure 18.) (2) Four of the known deposits (numbers 7, 8, 9, and 13) lie on the upthrow sides of normal faults, but not close to the overthrusts. Number 13 is on the upthrow side of a normal fault and on the downthrow side of the Green Mountain overthrust, and closer to it. It is dominated by this overthrust as much as by the normal fault. This latter relationship is possibly true of deposits 7, 8, and 9 also, but if so it is not clearly evident.

The bottom of the kaolin is nowhere exposed in the area, and well logs fail to mention the character of the underlying rock, except below deposits 4 and 8. The surface relations suggest that in many cases the kaolin rests on the quartzite. The only alternative hypothesis consistent with some surface relations is that the quartzite below (except under deposits 8, 9, 10, and 11) had been cut out by faulting and subsequent erosion prior to the kaolin development, and the kaolin subsequently developed on the lower gneisses. This alternative certainly is within the realm of possibility, but hardly within that of probability for the area as a whole. The conditions later to be described at deposit 4 suggest that the alternative holds at that place. Deposit 8 is known to be underlaid by gneiss instead of quartzite but at that place the presence of the gneiss checks with the surface conditions where the gneiss extends westward into the zone elsewhere occupied by the quartzite. Until more extensive mining or drilling operations are carried out it will be impossible to test the hypothesis for the area in general.

The kaolin is overlaid by drift, or by heavy talus where it is close to the steeper mountain slopes. The drift varies from 2 to 50 feet in thickness. At deposits 3, 4, and 6 its average thickness is from 20 to 30 feet. At the other deposits its average is thinner.

DESCRIPTIONS OF THE KAOLIN

At deposit 1 no kaolin is now visible at the surface, but it is within reach of a hand augur, and it has been penetrated by five wells. The deposit is of very small areal extent, but has a maximum thickness of 100 feet. The material is more sandy than in any of the other deposits explored.

At deposit 2 the material is also sandy. It has recently been penetrated by an exploring shaft 35 feet deep. The kaolin carries some fragments of foliated talc up to three-fourths of an inch across.

At deposit 3 the material was for many years worked for paper- and sagger-clay, but some years ago operations were abandoned because of the death of the manager and principal owner. The kaolin has a known thickness of 60 feet and underlies an area of at least 100 acres. It is remarkably uniform in grade throughout and is unstratified, but the body of the deposit, as well as the color banding, has a strong eastward dip. This deposit is remarkably free from concretions, but, especially in its lower levels, contains some large quartz geodes. Since mining ceased sliding, slumping, and accumulation of soil has so covered most of the deposit that it is not open to inspection, but the writer is informed by the former mine superintendent, with whom he visited the property, that the eastward dip carries the kaolin under a "cap rock." Unfortunately, no specimens of this "cap rock" could be obtained but from the former superintendent's description it was presumably quartzite or a quartz vein. West of the kaolin lie considerable deposits of ocher, which are separated from it by a ledge of massive vein-quartz similar to the veins cutting the quartzite of the mountains to the east. Across the center of the deposits with an east-west strike, passes a vertical "sandstone dike" of approximately eight feet width. The sand in its physical properties closely resembles the sugary, silica sand referred to above as a weathered product of certain phases of the quartzite. A typical section of the deposit is given in Figure 14.

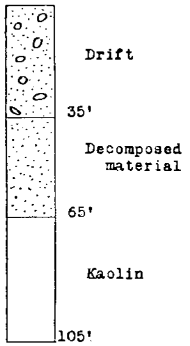

FIGURE 14.—Typical section at deposit 3.

Deposit number 4 lies farther up the Green Mountain slope than any other of the deposits except those numbered 10 and 11. This deposit has been

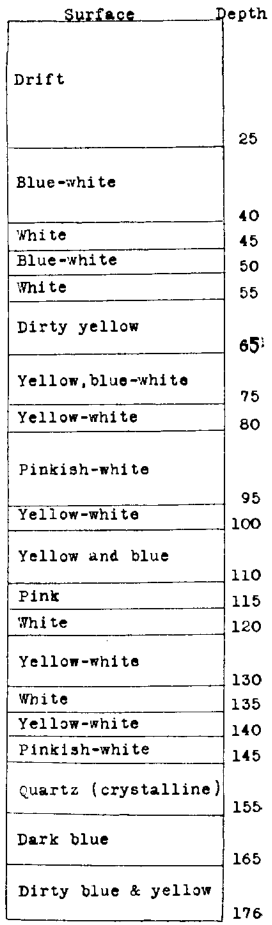

FIGURE 15.—Log of boring on west side of deposit 4.

extensively explored by drilling and two of the typical well logs, taken from the Vermont Kaolin Company's records, are reproduced in Figures 15 and 16. Below the kaolin on its western edge lies a hard, cream-colored, porous, sandy rock of fine grain. This rock consists of almost pure quartz with small amounts of minute mica flakes and ferric oxide specks. The rock is known to the writer only from the drill cores, and differs notably from any of the weathered phases of the quartzite with which he is familiar.

Deposit 5 is deeply buried below a water-logged sand and was discovered only through exploratory work with a drill. The total depth to the kaolin is 130 feet, and its penetrated thickness is five feet.

Deposit 6, has, in the past, been extensively worked for paper-, enamel ware-, sagger-, and fire-clays and it is at present commercially the most important. This deposit, together with deposits 4 and 5, are controlled by the Vermont Kaolin Company. Exploration of the deposit by the Merrimac Chemical Company, lessor, shows 1,500,000 tons of kaolin in sight. The overburden varies from 1 to 50 feet in thickness. A typical well log from near the center of the deposit is given in Figure 17.

On the eastern side of the deposit there is much yellow kaolin and very little blue, while the white lies constantly near the bottom. Many limonite concretions are also found on the eastern side. This is in contrast to the condition

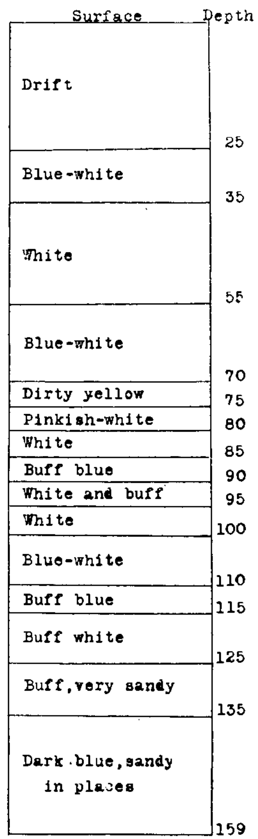

FIGURE 16.—Log of boring on east side of deposit 4.

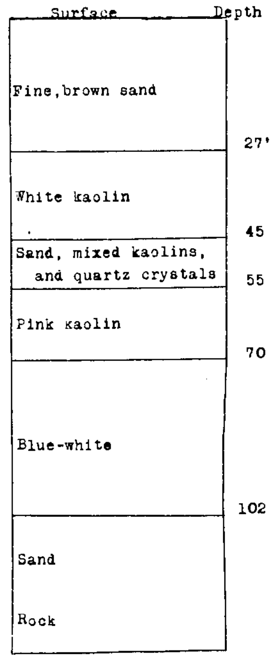

FIGURE 17.—Log of boring near center of deposit 6.

in deposit 4. The kaolin is unstratified, but contorted color streaks are common.

On the west the kaolin is bordered by iron ores and ochers, in which is much psilomelane. The kaolin and the chief mass of ocher are separated by a white quartz vein under which the ocher pitches. Small lenses of ocher extend into the kaolin or are contained within it. Within the weathered zone the quartz of the quartz vein is friable and resembles the weathered phases of the sugary quartzite of the area. Deeper the quartz of the vein is hard and white.

TABLE II

Mechanical Analysis of Overlying Decomposed Material from Deposit 6

Screen mesh (in inches)	Per cent of material retained
20	0.11%
40	15.55
60	44.44
80	17.77
100	5.55
Pan	16.66
Total	100.08

The kaolin is overlaid by till, consisting predominately of quartzite but with smaller amounts of gneiss and some limestone; and a mass of decomposed feldspar with some quartz and traces of mica, hematite, limonite, tourmaline, and garnet. A mechanical analysis of this decomposed material, showing its average coarseness, is given in Table II. This overlying material is an approximation to some of the residual material now developing from the gneiss believed to be possibly the northward extension of Pumpelly and Wolff's white gneiss.

In Table III two analyses of the kaolin of this deposit are given. Analysis "A" is taken from Jacobs,[1] and "B" from the records of the Vermont Kaolin Company. The latter analysis is of the white kaolin. The color of the blue seems attributable to the presence of a small amount of carbon.

A thin section of the kaolin from 15 feet below the surface shows a ground mass of very fine anisotropic matter with aggregate polarization. The mineral fragments large enough for identification are mainly quartz, kaolinized feldspar (both orthoclase and albite), and kaolinite. Many small fragments of garnet are conspicuous, with smaller amounts of tourmaline, zircon, magnetite, and gibbsite. Minute, opaque, black grains, possibly magnetite or some manganese mineral, occur sparsely scattered through the slide.

[1] E. C. Jacobs, *loc. cit.* p. 206.

The minerals which can be identified in the washings from the mill are chiefly quartz and decomposed feldspar. Scattered through the kaolin is considerable stony matter among which is found: (1) Fragments of typical, milky vein-quartz, (2) yellowish decomposed quartzite similar to some of the phases of the quartzite found on the mountains to the east, (3) dark, grey, spongy quartz from the fine voids of which weaker minerals have been removed by weathering. Small tourmaline crystals are identifiable in a few of these specimens, (4) limonite concretions, (5) quartz crystals, and (6) occasional pyrolusite and psilomelane concretions.

TABLE III

Analyses of the Kaolins of Deposit 6

	A	B
SiO_2	52.65%	58.00%
Al_2O_3	32.80	29.60
Combined H_2O	8.31	9.10
K_2O	3.66	....
Alkalies	....	1.05
Fe_2O_3	0.57	0.81
MgO	0.45	0.97
CaO	....	0.35
TiO_2	....	0.03
Total	98.44	99.91

Deposit 7 outcrops along the base of the quartzite ridge above the narrow valley of the Walloomsac River. The exposure is thin but the kaolin has been utilized to a small extent as a taxidermy clay.

Deposit 8 was worked in the fifties of the last century by the United States Pottery. It tests a high-grade pottery kaolin. The deposit is thin, and was penetrated a few years ago in making improvements to the Bennington Water System. It is underlaid by a fine-grained, orthoclase-albite-biotite-gneiss which shows little banding.

Deposit 9 is now covered, and its existence is known to the writer only from records which show that the United States Pottery formerly operated a shaft at the place.

Deposit 10 is controlled by the Green Mountain Kaolin Corporation. The deposit is not at present opened up, but considerable subsurface exploration has been done by means of shallow drilling. The wells, for the most part, were carried about 20 feet below the surface, and all of them stopped before the underlying bed rock was reached. This exploratory work indicates the presence of at least 1,000,000 tons of kaolin in place.[1] The overlying

[1] Data in the offices of the Green Mountain Kaolin Corporation, consulted and quoted by courtesy of Robert Healy, attorney for the corporation.

forest soil is from one to three feet in thickness. This is topographically the highest kaolin deposit in the area. At the northern end the kaolin is white, pale yellow, or buff. At the southern end it is bluish. Throughout it is, like the other deposits, massive, fine-grained, even-textured, and free from grit, but containing sand lenses and scattered pebbles and small boulders. A microscopic examination shows that the surface kaolin is holocrystalline with no amorphous material present. It is composed predominately of quartz with a smaller amount of kaolinite. There is very little feldspar or accessory mineral, and apparently no aluminum hydroxide minerals. Deeper the kaolin runs very high in kaolinite and related "clay minerals," although sandy lenses occur throughout the deposit.

TABLE IV

	North end	Middle	South end
SiO_2	60.14%	65.59%	65.34%
Al_2O_3	28.48	24.39	24.59
Fe_2O_3	1.51	0.66	0.78
CaO	trace	trace	trace
MgO	trace	trace	trace
Alkalies (by difference)	1.57	3.28	2.31
Ignition	8.30	6.08	6.98
Total	100.00	100.00	100.00

The chemical analyses given in Table IV are taken from Jones[1] and show no essential differences from the analyses of kaolin from deposit 6.

To the east rises a high ridge of quartzite and gneiss, at the foot of which the deposit lies. The nose of the ridge at the north end of the deposit is of quartzite and gives rise to a massive talus pile covering the northeast corner of the deposit. The gneiss is the white gneiss previously referred to and is quantitatively more important in the ridge than the quartzite. Ocher lies to the northwest, farther from the fault, and topographically lower. Northward in line with the fault and near the junction with the cross fault along the Walloomsac Valley is considerable iron and manganese ore.

Table V gives the approximate mineralogic composition of the kaolin deposits 6 and 10. The percentages for deposit 6 have been obtained by the writer by recalculating the chemical analysis, after a study of thin sections. The percentages for deposit 10 are taken from Jones[2] who made the calculation from the material coarse enough for the identification of the individual fragments.

[1] William F. Jones, Consulting Geologist's Report to the Officers of the Green Mountain Kaolin Corporation, 1925. Consulted by courtesy of Robert Healy.

[2] William F. Jones, *ibid.*

Deposit 11 lies below a ridge of gneiss, and, so far as available outcrops indicate the relations, is probably underlaid by gneiss. The deposit has not been drilled and neither its thickness nor areal extent are known, but subsoil conditions in the vicinity suggest it is of considerable extent.

Deposit 12 underlies a very shallow covering of fluvio-glacial drift. Samples were collected from the upper three feet of the deposit. This upper part is very fine-grained and flour-like in consistency where pure. Below it is more sandy. A microscopic examination of the kaolin from the lower, sandy part shows it to consist almost wholly of quartz and kaolinite, with small amounts of tourmaline and garnet which shows optical anomalies. Small fragments of psilomelane are scattered through it.

TABLE V

Mineralogic Composition of the Kaolins of Deposits 6 and 10

	Deposit 6	Deposit 10
Quartz	10.3%	7.0%
Clay minerals (kaolinite, etc.)	65.6	88.0
Feldspar	21.3	1.5
Accessories	3.2	3.5
Total	100.4	100.0

Deposit 13 is a small deposit overlaid by thin lake sands and clays. Many years ago a shallow shaft was sunk into it but nothing is now known of its thickness.

At various places along the fault line between deposits 10 and 12 kaolin is known to underlie the soil, but neither exposures nor well records are available to show its character, thickness, or extent.

THE AGE OF THE KAOLIN

The key to the age of the kaolin lies in its relations to three more or less determinable characters in the area. These are: (1) the bed rock formations, (2) the Cretaceous peneplain, and (3) the drift. There is also a determining character without the area: the Brandon lignite.

The bed rock formations tabulated in Table I are all older than the kaolin. The latest faulting of the Green Mountain front has been stated by Bain as having been of Jurassic date,[1] and the kaolin, both here and farther north, was developed after the last important faulting movements.

The topographic relations of the kaolin clearly show it to have been post Cretaceous-peneplain in its development.

[1] George W. Bain, *loc. cit.* p. 233.

That the deposits are pre-Pleistocene is shown by their overburden of drift. The means by which they were preserved from glacial erosion cannot be stated in detail until a more complete study of the glacial history of the area has been made, but in general it can be stated that the high gneiss and quartzite ridges to the east furnished a sufficient bulwark of protection against removal.

The Brandon lignite is one of the minor, but well-known formations of the state. In the northern part of the kaolin belt of Vermont the kaolins are intimately associated with these lignites. The area of this association is approximately 70 miles north of the Bennington area. The kaolin of the Brandon area, where it is associated with the lignite, is connected with that of the Bennington area by a broken chain of deposits, and like that of the latter area is associated with iron ore, manganese, and the Green Mountain front. It seems, therefore, highly probable that the kaolins of the two areas belong to the same formation.

Woodworth[1] has given evidence that these residual clays do not antedate the Miocene. Hitchcock[2] says with reference to the clays of southern Vermont: "Some of the kaolin beds contain stems of plants, which may possibly be allied to the fruits of Brandon of the same age." The "fruits" here referred to are from the Brandon lignite. Lesquereux,[3] on paleobotanical evidence, has dated the lignites as Miocene. Jeffrey and Chrysler[4] quote F. H. Knowlton as agreeing with Lesquereux' conclusions. Perkins[5] has since studied the lignites and definitely established the age of the Brandon formation as Miocene.

ORIGIN OF THE KAOLIN

The unstratified condition of most of the kaolin,[6] its topographic position, its constant relations to the structural features of the area, its consistent association with iron and manganese ores, and above all the intimate mixture within its body of minerals of such wide variations in specific gravity as quartz, kaolinite, tourmaline, and garnet are factors each of which argues strongly for its formation in situ, and combined they offer evidence which seems conclusive.

[1] J. B. Woodworth, The Brandon Clays, Rpt. Vermont State Geologist, Vol. IV, 1903-04, pp. 166-173.
[2] Edward Hitchcock, Geology of Vermont, Vol. II, 1861.
[3] L. Lesquereux, Fossil Fruits from Lignites of Brandon, Vermont, American Journal of Science, Series 2, Vol. XXXII, 1861, pp. 355-363.
[4] E. C. Jeffrey and M. A. Chrysler, The Lignites of Brandon, Rpt. Vermont State Geologist, Vol. V, 1905-06, p. 196. Quotation from F. H. Knowlton in the Bulletin of the Torrey Botanical Club.
[5] George H. Perkins, Fossils of the Lignite, Rpt. Vermont State Geologist, Vol. V, 1905-06, pp. 202-205.
[6] For an interesting discussion of the development of similar unstratified clays involving transportation see Fred R. Neumann, Origin of the Cretaceous White Clays of South Carolina, Economic Geology, Vol. XXII, 1927, pp. 374-387.

The only rocks within the area having the necessary composition to furnish the mineral complex found in the kaolin are the pre-Cambrian gneisses and the feldspathic and pebbly phases of the quartzite. Dana[1] records the contemporary formation of residual clays from the feldspathic phases of the quartzites in Berkshire County, Massachusetts, a few miles to the south. The writer has observed the development of clay from feldspathic and argillaceous beds of the quartzite in the silica quarries at Cheshire, Massachusetts, about 20 miles south of Bennington.

The feldspathic phases of the quartzite in the Bennington area are apparently too limited in their development to have produced such enormous quantities of residual matter, unless it be assumed that the proportion of these phases in the parts of the formation which have been weathered away, or are now concealed, was greater than in the parts now exposed. Such an assumption cannot be made as the formation is now exposed in many places near both its upper and lower contacts, and many high cliffs show the intermediate levels. Moreover it is very doubtful if the quartzite could, through weathering, be responsible for the associated iron and manganese deposits, although some beds near the base of the formation carry accessory iron and manganese minerals which were deposited in them from the erosion of the unconformable gneisses below. The quartzite undoubtedly furnished much, if not most, of the materials for the sands associated with the kaolin, and probably a very considerable part of the kaolinite and decomposed feldspar may have come from its feldspathic and argillaceous phases. The greater part of the clay, iron, and manganese material, however, is believed to have been derived from the gneisses.

The petrographic evidence of the gneiss parentage of the majority of the kaolin is not merely negative but is positive in that the gneiss contains sufficient garnet, tourmaline, zircon, and quartz, and in about the right proportion, to furnish these resistant constituents to the kaolin. It also contains the necessary parent minerals for the kaolinite, gibbsite, etc., of the kaolin and the limonite, hematite, psilomelane, and titanium minerals of the associated ores.

The minerals of the kaolin are all such as are either: (1) those highly resistant to ordinary weathering processes as garnet, tourmaline, zircon, quartz, and magnetite; or, (2) those formed by normal weathering processes as kaolinite, limonite, etc.; or, (3) minerals actually in katamorphic transformation as the kaolinized feldspar. Normal weathering processes, therefore, seem adequate to its development.

[1] James D. Dana, Manual of Geology, Fourth Edition, 1894, p. 134.

A structural evidence bearing on the origin of the deposits remains to be discussed. By reference to Figure 18 it will be seen that a reconstruction of the area as it was before erosion reduced it to its present condition shows that the kaolin now occupies a position formerly occupied by a portion of the upper

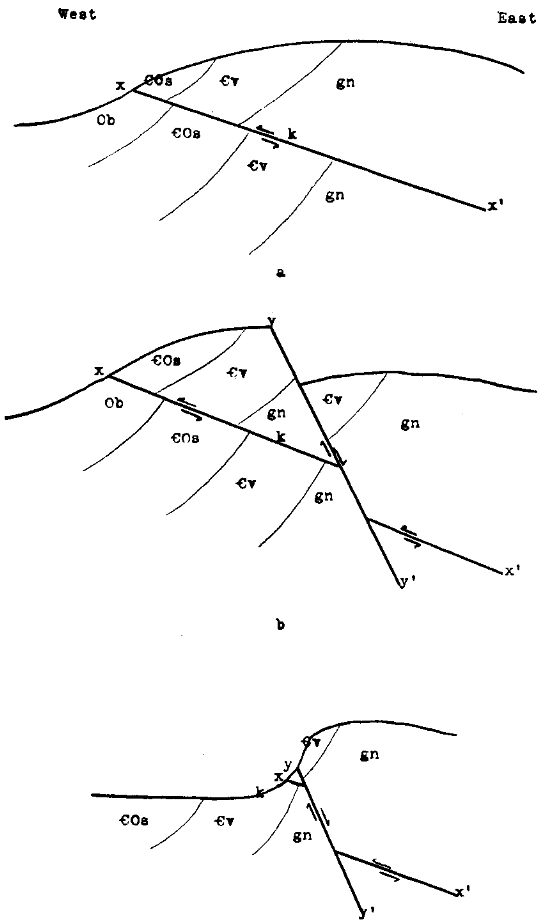

FIGURE 18.—Series of sketches to illustrate the relations of the developing structural features of the region to the kaolin. x—x', generalized plane of the early Paleozoic system of overthrusts. y—y', generalized plane of the later Paleozoic system of normal faults. k, constant showing position of final kaolin development. Formation symbols the same as in Table I. a—Diagram of early Paleozoic conditions following the Green Mountains overthrusting movements. b—Diagrammatic representation of the late Paleozoic conditions after normal faulting. c—Representation of late Tertiary conditions after peneplanation, rejuvenation, and erosion. Quaternary development has covered much of the kaolin with drift and buried the slope k—x—y under rock slide and talus.

parts of the Woodford gneisses. If the kaolin was developed by the weathering of the portion of these gneisses overlying its present position no transportational element, or element of movement other than slumping and settling, was involved. According to this view the associated iron and manganese ores have developed by normal weathering processes from the ferro-magnesian minerals of the gneisses, while the kaolin had a parallel development from the feldspathic constituents. The associated sands and residual silicas have developed, parallel to both the ores and the kaolin, from the more siliceous portions of the gneisses and from the quartzite. The iron-manganese ores and the kaolin are found in actual contact, or separated by only a few feet, but usually as distinctly separate units. In a few cases the ores and the kaolin intermingle. On the other hand the kaolin and the quartz sands are less sharply separated, the latter, in many cases, occurring as lenses in the former or cutting across it much as a vein cuts a formation. The differentiation of these three residual materials may have been accomplished partly by their development from distinct phases of the overlying gneisses and quartzites, but it must have been in part, at least, on the basis of differences in solubility and specific gravity. This of necessity implies transportation, but in this case the transportation involved seems to have been for a short distance only in which these katamorphic products were not removed beyond the area formerly occupied by their parent rocks.

The diagram "c" in Figure 18 shows a wedge of gneiss below the quartzite at the western base of the Green Mountain front. Such a wedge is actually found in places in the area. That such is not found in all parts may be due to variations in dips and positions of the fault planes, to varying amounts of erosion, or to burial beneath talus and rock slides. These talus piles and rock slides are of much greater development than a cursory examination of the area would indicate. This is due to the fact that in places soil has developed over them completely obscuring them from view.

CONCLUSIONS

A study of the kaolin, its structure, composition, and relations leads the writer to the following conclusions:

1. The deposits are residual rather than transported in type.
2. The kaolin has been developed by normal weathering processes. The parent rocks are primarily the pre-Cambrian gneisses of the area, and to a less extent the feldspathic and argillaceous phases of the quartzite.
3. The kaolin, associated sands, and iron-manganese ores represent different members of the same formation.

4. The formation is of Tertiary age and was protected from glacial erosion by its topographic position at the base of cliffs against which the glacier impinged. It is impossible at this time to state definitely how much, or what parts, of the Tertiary were involved in the development of the formation, except that at least a part of it is Miocene.

5. The known deposits do not form a continuous belt, but there is some evidence that their continuity is more nearly complete than surface conditions indicate, and that originally it was complete.

THE ROCKS OF VERMONT

G. H. Perkins

I hardly need say at the outset that rocks of various sorts are most familiar objects in Vermont. Rocks are everywhere in all parts of the state and to many of our citizens much more of a trouble than an asset. How to get rid of these superabundant rocks is often more of a question than what may be known about them, what can they tell us of their nature, origin, history, etc.

If it is true, as it surely is, that there are "Sermons in stones," then it must also be true that some knowledge of these apparent intruders in our fields may be interesting and sometimes important. The frequent inquiries as to the character, uses, value, etc., of stones picked up at random here and there that come to the geologist give abundant evidence that there are many who are interested in these common objects. And here let it be understood that the following pages are written, not so much for the geologists who may chance to read them, as for those, who without geological knowledge, and often little time or opportunity to acquire it, do nevertheless wish to know what may be possible to them as to the stones which they see all about. For this reason much of what is to follow will seem very familiar, perhaps trivial, to the trained geologist, but it is to the man on his farm, the school boy who goes for the cows, the man who makes the roads, and shovels earth, for such I want especially to write and therefore as plainly and as free from technicalities as may be possible. In some of its phases it is not possible to write simply and clearly of the geology of our State, for the subject is far from a simple one. There is great confusion and complexity found in studying some areas in Vermont, much more than in many regions of equal size. Not so of all parts of the State; not everywhere is the record of the rocks difficult to understand. Through the labors of geologists in past years many puzzling outcrops have been made to tell the story of their origin and formation, much light has been thrown upon many problems, before unsolved. Because of this those who are willing to give some time and study to the geology of Vermont can readily learn much that is of interest and value. While a great deal can be learned from what has been written in any of the numerous accessible books that have been published during the last few years, as well as from some that are older, it is important that one remember that in any branch of nature study, the best and in some respects the only, knowledge of the objects studied is to be gained by studying the things themselves. Both should be used—books telling about natural objects, and a thorough study of the actual specimens, of whatever sort they may be. It is not necessary to say that the aid of a good teacher is invaluable, and yet one who is really in earnest in search for facts can get a lot of information and enjoyment as well, from his own careful observation of the commonest things. Only let the student understand that everything which is about him, plants, animals, stones, whatever, has a story to tell, a lesson to give and that it is all well worth while and will abundantly repay the most diligent effort.

In geological works the words rock, stone, mineral are used and this brings up the question, What is a rock? What is a mineral? as distinguished from each other. As the word is used by geologists and as it will be used here, rock means, with a few exceptions, a more or less compound mass, usually hard, while a mineral is generally simpler, a combination of chemical elements. In a few cases rock and mineral may be the same, as quartz, which may be called by either name, so that no absolutely hard and fast line can be drawn. In a rock, as granite, as will be seen later, the component parts may be simply associated not chemically united, while in a mineral they are in combination. In some few minerals there may be only one chemical element, as gold, native silver or copper, in others only two, as quartz, or many ores of iron, but in most there are several and may be a considerable number. In a recent textbook, rock is defined as follows: "The word rock geologically speaking means the material composing one of the individual parts of the earth's shell. In ordinary usage, a rock means something hard and firm, but geologically a rock may be composed of soft substance, thus a bed of clay, or volcanic ash may be considered a rock as well as a mass of granite."[1] So, too, a bed of sand, a block of ice may be called rock. It may be well to add that it is not intended to criticize common usage, but only to call attention to scientific usage.

Although the list of minerals found in various regions of the earth is rather long, those kinds which are found in abundance are not many. The larger number are found only in limited localities and not in large quantity.

Where to draw the line between rocks that are called common and those which should be called rare is to some extent a matter of opinion. Obviously it is not possible to ascertain very much about the material which forms the greater part of the interior of the earth since our deepest borings below the surface are relatively very shallow when compared with the entire depth from the surface to the center. Our positive knowledge is only of a thin layer on the surface and were it not for the many changes, upheaval, overturning, etc., which have disturbed this crust, we should know much less.

[1] Textbook of Geology, Pirsson and Schuchert, Part I, p. 254.

Vermont being but a very small part of the earth would not be expected to afford a great variety of the materials found here and there on the surface, but a larger number than is found in many greater areas may be collected here and a series of Vermont rocks would illustrate the more common rocks of the world very well. Of course many varieties would be wanting in a Vermont collection, but we may find here the most common and abundant kinds as found all over the world. There will be more to say as to making a collection of Vermont rocks at the close of this article.

Using the word rock in its geological meaning, a compound of several minerals, we may follow the scientist in classifying rocks in three great groups. These are named Igneous, Sedimentary and Metamorphic.

IGNEOUS ROCKS

Igneous rocks are those which having been molten have been forced from the great mass below the surface through the upper layers until they have by various means been exposed. They are cooled and therefore hardened lavas. In some cases Igneous rocks have always been exposed on the surface, but not infrequently their character and environment show that at first they did not quite reach the surface but were held by surface layers of older rock, this latter having been removed by erosion or decomposition. As we shall see later, most of our granite was thus covered at first. Although not as abundant on the surface of the earth as are the Sedimentary and Metamorphic rocks, it must be true that the great bulk of the earth is composed of Igneous rock for the other two classes are not found far below the outer surface, relatively to the entire mass. As Igneous rock is always thrown out by volcanic action it is evident that it may be of any age from the oldest to the newest through all the geologic ages, as long as there is any volcanic activity. The most important Igneous rocks found in Vermont are Granite, Syenite, Diorite, Porphyry, Basalt, Peridotite and various other varieties which occur only in dikes and in very limited quantity. Some of these cannot be easily determined and the student must have laboratory facilities if he is to be certain of the nature of his specimen.

GRANITE

In this State, Granite is the only Igneous rock that is of economic importance. New Hampshire is called "The Granite

State" but of late years Vermont has produced more of this stone than any other in the country.

It may be well to notice that several allied kinds of stone are called Granite in trade which are geologically different. Ordinary Barre Granite may be taken as typical granite. This is always of some shade of gray, from very light to very dark and composed of little bits of three minerals, Quartz, Feldspar, Mica. The shade of gray, size of grains, etc., varies greatly, but in all kinds are the three minerals named. Usually these are readily determined. The quartz is like glass, clear and transparent, the feldspar white and opaque, the mica in little scales, usually black, known to be underlaid by gneiss instead of quartzite but at that more rarely brown or very light. It will readily be seen that the shade of one or another variety of Granite depends mostly on the color and abundance of the contained mica. Abundance of black mica necessarily makes the whole dark, while abundance of light mica makes the stone light. In other granite localities the granite may be of various shades of red, but all Vermont granite that is quarried is gray, though there is a little pink granite in the northern part of the State, but it has never been quarried. The three minerals which compose most of our granite are complex in their chemical composition and therefore of course the chemical analysis shows the presence of many elements, but the examination which anyone can make by carefully looking at a bit of the stone is, as we have seen, very simple. Because of the manner in which granite is formed, different layers in the same quarry may be exactly alike, or they may be very different, in shade and in the size of the bits of quartz, feldspar and mica, in one part of a quarry the stone may be very fine in grain while not far away it may be very coarse. If as we have seen our Granite is a volcanic rock, there must at some time have been not a little volcanic activity and it seems to be entirely unconnected with ordinary mountain formation for without exception our granite masses, such as Kirby Mountain, Robeson Mountain, Millstone Hill, Christian Hill, Black Mountain, are all east of the Green Mountains. It is noteworthy that neither in the Green Mountain mass nor anywhere west of them is there granite. The volcanic activity by which the magma, or molten mass, out of which the granite crystallized was confined to eastern Vermont from which it extended farther east in New Hampshire. As the molten stream was forced upwards from below the immediate crust of the earth it cooled and the quartz, feldspar and mica crystallized as we now find them. The grain of the granite depended much on the rate of cooling and other conditions. If the cooling is slow, the crystallized ingredients are larger and if the cooling has been under pressure, the structure of the stone will show this condition.

That most, if not all, our Vermont granite was formed when pressed by other rock seems to be indicated by its structure. As now found the granite masses lie at the surface uncovered, but if we look carefully about the quarries we shall always find that along the edges of the granite is other stone, usually a dark slaty stone, a schist. By examining this bordering stone it will be seen that if its layers are carried up they go over and cover the granite. That is, the melted mass which became the granite came up under the schist and was entirely covered by it for perhaps a long time and that we now find the granite knobs uncovered because decomposition and erosion have during the ages since carried off the top.

As to the exact geological age of Vermont granite, authorities are not fully agreed, but at any rate it is younger than most of the rocks of the State. In some places there are two varieties of granite, one evidently older than the other. By carefully reading what has been written about our granite one may understand how much may be learned from careful examination of a bit of stone. I wish to refer here to a very thorough study of some of the Vermont granites by Dr. Robert Balk which is given in the Report on Vermont Geology immediately preceding this. Parts of this article may be too technical for the general reader but much will be found interesting and instructive.

A very peculiar variety of granite is found in small areas in Bethel, Newfane, Northfield and especially in Craftsbury. In this "Nodular Granite" some of the black mica (biotite) is in the form of concretions which are from an inch to two inches long. These concretions are scattered through the mass in considerable abundance.

Granite is quarried in Vermont in Adamant, Barre, Bethel, Derby, Dummerston, Groton, Hardwick, Newport, Ryegate, Williamstown, Woodbury, and occurs in several other localities, and in boulders in all parts of the State.

SYENITE

Syenite does not occur in Vermont in large masses except at Windsor, on Mount Ascutney, and at Cuttingsville and in both places Syenite is associated closely with a variety of other Igneous rocks. Syenite differs from granite in the absence of quartz and the much greater amount of feldspar in its composition. It is most readily recognized by the presence of black hornblende in place of the mica of granite. This hornblende is a compact, hard material, never splitting in thin plates like mica. In some specimens, syenite very closely resembles granite in color but is usually easily distinguished by the characters given above. Other varieties are unlike granite. Most of the "Red Granite" of trade is syenite. What is sold as "Windsor Green Granite" is good syenite. The rocks of Mount Ascutney have been more thoroughly studied than those of other Vermont mountains. In Bulletin 309, United States Geological Survey, Prof. R. A. Daly has published a very complete study of the rocks of this mountain. Professor Daly shows that the entire mountain is built up of Igneous rock and is a remnant of a greater mass which has long since been carried off. At some time long ago volcanic activity must have been powerfully exercised in the region about this mountain, probably sometime after the Green Mountains were piled up. The different species of rock found here will not be given as without the publication named above and without laboratory appliances it would not be possible to identify most of them.

In appearance the Windsor syenite is a dark olive, differing somewhat in shade in different layers. The syenite of "Granite Hill" in Cuttingsville is a bright, black and white stone like gray granite. The Cuttingsville area has been studied by J. W. Eggleston and his Report on the locality is published in the Eleventh Report of Vermont State Geologist, page 167, 1917. As at Ascutney, there are several kinds of eruptive rocks at Cuttingsville, but for the same reason as at the former locality, they will not be enumerated here. I should, however, mention the fact that there are small deposits of true granite in the Ascutney area but none in the "Granite Hill" area. Also it should be noted that at Cuttingsville there are several varieties of Syenite. As noted, these are the only masses of Syenite of considerable size in Vermont, but small masses are found in Braintree, Bethel, Randolph, and a few other localities.[1]

PERIDOTITE

Peridotite is not widely distributed in Vermont but it should be mentioned as it occurs in some localities, as Eden, Lowell, Randolph. This rock is interesting as the source of some important minerals. In Vermont only a few minerals are associated, but elsewhere this rock is the source of Chromium, Nickel, Diamond, Platinum, and some of less value. Here is the source of Asbestos and Chrome Iron and also of Serpentine, such as the Roxbury "Marble." Typical Peridotite is a hard, dark-colored stone that like granite and other Igneous Rocks has been forced up from below the surface as molten material. Soapstone is also formed from this rock, as also Talc.

Although Granite and Syenite are the only large masses of Igneous rock in Vermont, there are many smaller masses in the form of dikes. In these dikes, of which there may be several hundreds in the State, as there are over fifty in Chittenden County, as many more in Grand Isle County and so on, though probably there are more in these two counties than elsewhere, a great variety of material is found. Formerly all sorts of dike rock was spoken of as Trap, but this term has been abandoned by geologists as being altogether too general, since the name included many different sorts of material. I shall not attempt to enumerate the different names which have been given by specialists to these dike rocks, much less try to give characters by which they may be distinguished, for this is work for an expert.

[1] In giving localities where one or another species of rock may be found, it is not intended to give a complete list, as in many cases this would be too long, but only the more prominent outcrops of the rock named.

A "Dike" is usually easily recognized as a band of material which has been intruded into and through the mass of a different rock. Not always, but in this State usually, the intruded rock is of dark color. It may be only a fraction of an inch or several feet in width. It may appear for only a short distance, or it may be traced for some miles. Dikes are much more common in western Vermont and on the shores of Lake Champlain than elsewhere (in exploring the shores of Grand Isle I found over forty) and there are not many in the eastern part of the State. Evidently after the main rock of the west part of Vermont was deposited, there was not a little volcanic disturbance. All of the dikes are volcanic rock which has been forced from below the surface as molten lava. In some cases, as for example, at Shelburne Point and elsewhere, the lava overflowed and was hardened in a more or less thick sheet about the main dike. East of the Green Mountains the volcanic activity seems to have been mostly manifested in the granite upheavals, which were evidently much more violent than those which produced the dikes on the west.

SEDIMENTARY ROCKS

Sedimentary Rocks—rocks made from deposits, usually under water, the materials of which were originally taken (secreted) from the water by corals, mollusca, corallines, etc., or from ground rock washed from older land. Sometimes, though rarely, sediments may be formed on land by wind-blown sand. For the greater part Sedimentary Rocks have been formed in the sea, but there are fresh-water deposits also. These rocks are the familiar Sandstones, Limestones and Shales. In Vermont they are, in unaltered condition, found mostly west of the Green Mountains, especially along the shores of Lake Champlain and eastward to the mountains. As we shall see later, there are great beds of much altered Sedimentary Rocks in most parts of the State and in the Green Mountain mass, but those beds that are unchanged to any great extent from their original condition are located as just stated. All the larger islands and points on the east side of

Lake Champlain are examples of Sedimentary Rock. With small exceptions, these rocks are of the oldest fossil-bearing formations, Cambrian and Ordovician. Therefore as has often been noticed, Vermont is geologically one of the very oldest parts of the United States. There are very old rocks in many states in greater or lesser areas, but in no other state, so far as I can recall, is the entire area, with very small exceptions, covered by what geologists call Paleozoic rocks. Lest some reader, not well posted in geology be misled by this statement, let me hasten to add that I refer to the rock formations not to the sands, clays, etc., of the surface. These are of the latest formation.

Sedimentary Rocks when first laid down, unless the shore on which they were formed was sloping, must have been horizontal in bedding, but now, because of disturbances already mentioned and others to be noticed in what follows, most of the beds and layers seen are inclined or even folded in every manner. Everywhere, we see in the exposures of Sedimentary Rocks, the results of disturbances by which the beds have been upheaved, broken and even completely overturned by the great earth forces. In former Reports I have mentioned the really wonderful exposure of the cliff facing the lake at Rock Point. Because this is very interesting in itself, and because it illustrates very finely the result of enormous changes that have taken place in the earth's crust, I want to write of it here with considerable detail. The conditions at Rock Point are easily observed by anyone who will look carefully at the cliff as seen from a boat or on the shore just north of the Point. The first feature of this cliff, which runs down into the water, there being here no low shore, evident to one who looks is the black rock next the water and continuing into the Lake, and rising almost vertically from the water. This black rock is about fifteen feet above the water. How far below? Over this is a much greater thickness of light, calcareous sandstone, the whole cliff rising vertically (above mean water) seventy feet. The same conditions, though seen not as plainly are found at several other points, as St. Albans Bay, Malletts Bay, and, with some difference, at Snake Mountain. The obvious question is, How did this happen? Elsewhere north on the Lake we see in many places as on Colchester Point, the same black rock with no other rock above it. A study of the light rock above and of the black rock below has long since told geologists that the rock above, the sandstone, is of Lower Cambrian age and that the black rock below is Upper Trenton (formerly Utica Shale). But the geologist will at once say "You have put a rock on top millions of years older than that below next the water." Of course older rocks must be deposited before those that are more recent.

This is what has happened, and the evidence is not to be doubted. Beginning north in Canada and extending south

through western Vermont near the Lake shore, at some time very long ago came a great earthquake or something of the sort, and broke through many feet of the rock for many miles. Then the beds of rock east of the crack were raised hundreds of feet above the beds on the west. The rock beds on the east were not only lifted, but by force from the east, pushed westward over the beds on the west side of the great break. At first the order of the beds was on top Upper Trenton, then Lower Cambrian. In geological order there should be several beds between. These, if they were formed in this region, have all been long since carried away, that is, before the black shale was formed on dry land. After the eastern beds were pushed over the western the order was, first black shale, second sandrock, third black shale, lastly sandrock. During the ages which have passed since the "Great Fault" was made the top beds of black shale have been entirely removed, by decomposition and erosion, leaving three beds, the sandrock at the top, the shale at the water edge, the first bed of sandrock down deep in the Lake, so that now all that can be seen are the second and third beds, the Lower Cambrian Sandrock above and the Upper Trenton below. I have given these details in order that one visiting any of the localities mentioned above may clearly understand the incredible facts and thus get some little idea of what great things have happened during the building of Vermont and during past geological ages all over the world.

Sedimentary Rocks are in layers, more or less distinct (beds or strata) and often contain fossil shells, corals or other organisms, but by no means all the beds. Some layers are completely filled with these remains of animals or plants that lived in the ancient seas or on the land, while other layers contain only a few and there are others, sometimes great masses, in which no evidence of former life can be found.

Considering more specifically the different kinds or species of Sedimentary Rocks we first take up

LIMESTONE

Most Limestone is easily recognized, but should there be any doubt a sure test is made by dropping on it a little acid, preferably hydrochloric, and if there is any effervescence, this says limestone. All Limestone is more or less pure lime carbonate and acid releases the carbonic acid and causes foaming. A little Limestone in a few localities is of chemical origin, but by far the greater part everywhere has been held in solution in sea water from which lime is separated by a great variety of animals, as shellfish (clams, oysters, snails, etc.). There are innumerable micro organisms in the sea which form limestone shells and these though so very small individually, by immense number add much material to the sea bottom, which accumulates in great beds and later by upheaval of the sea bottom or falling of the sea level are finally seen as beds of stone.

Throughout the ages, probably no source of material has produced so great masses of rock as coral animals. While such sources may not contribute very large amounts year by year yet during the immensely long ages of geological time the accumulation has been great beyond computation. Now, Limestone forms an amount of material on the surface of the earth which no one can estimate. And all these processes are still going on and must as long as the earth goes on. Geologists as well as others speak of the geological ages as of the past, different from the present, but really we of today are just as much living in a geological age as if we lived millions of years ago.

In Vermont our rocks are not mainly limestone, as is true in many localities, but, as has been noticed, they are mostly Igneous and Metamorphic.

Undoubtedly, as will be shown later, a great deal of the rock structure as we now see it has at some ancient time been very unlike its present condition but the enormous forces that have been in action in past time have so transformed the physical features of the State that only long and careful study of present conditions can make known what these conditions were. In some localities the record has been made over and over again and each new record more or less completely obscured those that preceded.

Typical Limestone is almost wholly confined to areas west of the Green Mountains. There are beds of impure Limestone east of the mountains, but true Limestone is mostly found in the Champlain Valley and does not usually extend far east of Lake Champlain. There are a few exceptions to this, but for the most part it holds good. Very little of our Limestone is light in color, mostly it is dark gray, or at least a decided gray. Some beds are black. As would be expected from the way in which they are formed, all sedimentary rocks may contain fossils, but these are most abundant in Limestone in Vermont. In some localities this stone contains more or less magnesia. It then is less effervescent and is Dolomite.

SANDSTONE

The "Redsandrock" of western Vermont is well known to geologists. There are shales and limestones which are assigned to this "Formation," but the prevalent rock is a Sandstone of various shades of red. There is abundant evidence that in very early geological times this formation was several hundreds of feet thick and covered a large area in what is now Vermont. Remnants of the former widespread Sandrock are now seen in Snake Mountain, Mount Philo, Hog Back in Monkton, Red Rocks in Burlington and many ledges running to and beyond the Canada Line. The origin of Limestone has been discussed, that of Sandstone is very different. Formed nearly always in water, sometimes deep water, but usually made of the consolidated sand of ancient sea beaches, this stone is regarded, in most instances as indicating a former rather shallow water sea into which the eroded rocks of the land adjacent was washed. All sand is broken up rock, hard rock, usually quartz or quartzose, and sand consolidated is Sandrock. Therefore before there could be sand there must be older rock which could be ground into sand. As we shall see, soft rock ground up makes a very different rock. As today on any sea beach we find shells, etc., so in many of the sandstone layers we find fossils of all kinds. Most of our Vermont Sandstone represents old sea beaches, but here and there the Sandstone seems to have been formed in deeper water and has lime in its composition. In the "Champlain Marbles" we have an excellent example of this grading from a pure sandstone to a very calcareous sandstone. The red or reddish color of our Sandstone is mostly caused by contained iron oxide (iron rust). More or less of this iron oxide determines the color of the stone. In geological age the Redsandrock is considerably older than most of the Limestones, being placed in what is known as Lower Cambrian, which was formed before the Ordovician, which is the age of the Limestones. A little Limestone in Swanton, St. Albans, etc., is of the same age as the Sandrock.

SHALE

As Sandstone is consolidated sand so we may consider Shale as consolidated mud. The processes by which each is changed to stone are quite different however. Usually Sandstone is made of grains of sand cemented into a solid mass, while Shale is simply hardened, clayey mud showing no grains whatever. In Vermont our shale is dark or black in color, is often soft, and splits in plates of various thickness. Shale in many respects is much like Slate, but it differs in some respects, as will be noticed when we come to Slate. Typical examples of Shale are found at many points on the shores of Lake Champlain. Over North Hero and Alburg all the rock is black Shale. In many localities, as Shelburne Point, the Shale is cracked in hardening and white calcite (carbonate of lime) has filtered through the mass and filled it with white veins, which form a marked contrast to the main rock. At some localities the shale is greatly disturbed, folded and overturned. Elsewhere it is nearly horizontal and undisturbed. Generally the Shale does not contain fossils, but at some limited localities a few may be found. Iron pyrites is not infrequently contained in the shale and its golden color sometimes arouses curiosity, but aside from other characters, pyrites is very hard and if powdered and heated gives out sulphur fumes.

During the last few years a new study in geology has sprung up, Sedimentation. One phase of this study is an effort to discover the conditions which existed when the rock was formed by study of structure thus getting some knowledge of those ancient times, by examining the structure of the rock then formed.

The three classes of rocks named embrace most Sedimentary Rocks of Vermont but there are of lesser importance one or two other kinds in usually only small masses. One of these which is so unlike other rocks in appearance that it always attracts attention is

CONGLOMERATE

When a gravel bank of any sort is permeated by a solution of silica or lime by which the pebbles are cemented into a stony mass, we have Conglomerate. As this stone is found in very old formations and is now forming, it may be of any age. Conglomerate, or "Pudding Stone," is not as common in Vermont as in some other states and usually it is found in small deposits. The "Irasburg Conglomerate," so named by Professor Richardson in 1905, is of wide distribution from Irasburg south through the eastern part of the State. As to this Conglomerate Dr. Richardson writes as follows: "Its conglomerate nature is unmistakable. Pebbles of granite are held in the folds of the highly metamorphic micaceous portion. One of these is six inches long and four inches wide. Fragments of diorites, highly metamorphosed schists and quartz pebbles are also present in large numbers and the bands of limestone are interbedded with the more micaceous portions. The structure of the conglomerate strikingly suggests a rapidly sinking sea upon whose shores these calcareous sands were deposited.[1] In such a Conglomerate as this all sorts of material are found, and the rock might perhaps properly be included under the following heading, Metamorphic Rocks, but it is convenient to speak of it here. When instead of rounded pebbles a Conglomerate is made up of angular pieces of stone, it is called Breccia. In Vermont this is, some of it at least, older than the true Conglomerate with its water-worn inclusions. Very good examples of Breccia are found in some specimens of "Champlain Marble" and on the east shore of Isle La Motte there is in the limestone a bed of this rock which is described in the Fourth Report, Vermont State Geologist. Naturally, the pebbles in Conglomerate are of quartz or other hard stone, as any other would

[1] Rpt. Vermont Geologist, Vol. V, 1905, p. 82.

be reduced to mud. In a Breccia it is evident that the inclusions have not been transported and rounded as in Conglomerate and therefore have come from nearby places. Breccia is much less common in Vermont than Conglomerate.

METAMORPHIC ROCKS

The two classes of rocks that have been discussed occupy vast areas on the face of the earth, but in Vermont by far the greater portion of our rocks belong to the Metamorphic division. Of such rocks the Green Mountains are wholly built up, also the Taconics, as Equinox, Green Peak, Bird Mountain, etc. The foothills of the Green Mountains and adjacent areas also abound in these rocks. In some of the deposits the change from the original condition is not very great, elsewhere it has been so great as to entirely efface all characters which indicate the former condition. It is this great metamorphism which makes the student of Vermont geology so much trouble and now and then makes certainty well nigh, if not wholly, impossible. As in ancient times a record on a parchment was sometimes more or less fully erased and a newer record written over the old, so in some parts of Vermont, the older record has been obscured by a later, perhaps in some cases more than once.

A variety of agencies, heat, pressure, folding, chemical change, may work together or only one or two, to produce change. As would be supposed, Metamorphic Rocks may be derived from any sort of existing material whether igneous or sedimentary. In rare cases the change has not obliterated all fossils which limestone may have contained as in some of the marble of West Rutland where the deeper strata have retained a few of the old fossils in recognizable form, as illustrated in the Sixth Report of the Vermont State Geologist, page 12, Plate V. Usually the rocks during metamorphism become harder and more crystalline. It would be impossible, even if advisable, to name still less to discuss all the very many varieties of Metamorphic Rocks found in Vermont, for there are a great many species which have been named by one or another geologist and as these rocks are studied, new varieties are coming into being. In writing in one of the Bulletins (13), "Lithology of Connecticut" of the Connecticut Geological Survey, Professor Barrell writes as follows: "The uplifts of mountains and the resultant erosion of geologic ages expose to the surface conditions of pressure temperature and chemical action rocks which were formed under quite different environments. Destruction of the old rocks results, and in the incoherent state, the products of rock decay are transported by surface agencies, sorted in the process, and deposited as sediments. This completes the destructive half of the cycle. . . . Water of porosity is expelled. Some of that in chemical combination follows. Cementation takes place and the products become solid rock. But mountain-making forces may add their enormous pressure to that already due to the weight of the sediments, and the temperature becomes still higher either owing to the work of mashing or because of neighboring igneous intrusions. Water in consequence may be completely expelled. Minerals of greater density may be formed. Carbon dioxide is also expelled in so far as silica is present to again claim the metallic oxides. In obedience to these changed chemical and physical conditions new minerals consequently arise and a recrystallization of the whole rock results, generating schists, gneisses, quartzites and marbles. This is the constructive half of the metamorphic cycle. The process, however, stops before completion. . . . The rocks therefore are not to be studied as things by themselves, but as containing a record of the vicissitudes through which they have passed." The above processes never stop, but as long as the world is in its present condition, they must go on, in some localities very slowly, in others more rapidly and obviously, but change is everywhere and all the time. And nowhere are changes in the rocky constitution of an area more obvious and more numerous than in the small area we call Vermont. Writers on the Metamorphic Rocks classify them in different groups. In this the grouping given by Barrell will be followed. Barrell makes three groups, namely: Gneisses, Crystalline Schists and Marbles, all of which are well exposed in Vermont. Aside from the Granite, no rocks are of as great economic importance to the State as some of these, as will be seen in what follows when we consider Marble and Slate.

Had no metamorphism taken place in ancient geologic time Vermont would now be the loser by several millions of dollars annually.

Of the many varieties of Metamorphic Rocks found in almost every town in Vermont only some of the most important will be especially mentioned. When localities are named it is in few cases because the species given is present only in that locality, but only because the rock is readily found in that place. Some of the varieties are to be seen in almost every town in the State, others in only a few. Perhaps the most generally abundant of the Metamorphic Rocks found in Vermont is

GNEISS

In many of its varieties Gneiss closely resembles Granite and contains the same minerals, quartz, mica, feldspar, and sometimes it is metamorphosed Granite. But there is this usually obvious difference, Gneiss is always banded, not always very plainly, but usually. That is, the chief minerals, especially the mica, are in layers, while in Granite they are not, but well mixed. It is most probable that much of our Gneiss has been formed from sedimentary rocks and that these were in the early period of the formation of our rocks far more extensive than at present. When Gneiss is formed from Granite it is obvious that no great chemical changes need occur, but when made from Sedimentary Rock there must be considerable redistribution of the chemical materials by which distribution new minerals are formed. Sometimes a mass of Gneiss is folded or crumpled so that the bands of black mica are very conspicuous and thus the "Gneissoid structure" is well seen. Excellent specimens of this rock may be obtained in many places especially in the Green Mountain region. After what has been written of the general prevalence of Gneiss, it is unnecessary to give a list of localities, and to speak of the many varieties, each characterized by the minerals found in its composition, would require more technical description than seems best in this article.

SCHIST

Schist is very common in most parts of Vermont and occurs in a great many varieties, some of which are widely distributed, others local. Schist may be described as a rock having a more or less crystalline structure, sometimes coarse, sometimes fine and compact, which splits into laminæ, or layers, of various thickness. Professor Barrell, "Lithology of Connecticut," page 115, says of this rock: "Schistosity implies the capacity to break upon any one of a parallel system of planes. Thus schistose rocks resemble Slates in possessing the property of cleavage, but schistosity is distinguished from slatiness by the waviness or knottiness of the cleavage surface and is developed in rocks which are more coarsely crystalline and in some cases closely banded. Schistose structure is determined by the development of minerals in parallel directions so that the planes of cleavage of innumerable crystals are parallel giving a continuous surface of easy breakage, Where the minerals are segregated into planes only the mineral having cleavage will be visible upon the surface. To ascertain the other minerals it is necessary to examine a fracture across the cleavage." Some of our Vermont Schist hardly meets this definition, but it is not possible to give a complete definition of Schist, for there is so great variety that all cannot be included in any definition. Each kind should be defined by itself. To add to the puzzle, some Schists grade into Slate so gradually that no line can be drawn between the two. This is not usual, as the origin of Schist and Slate, true Slate, is in each rock very different. In deciding as to the kind of whatever Schist one may find it is better, and in most cases necessary, to seek advice from some expert. As will be seen in the following descriptions some kinds of Schist are easily identified, but many are not. Only a few of the more readily identified Schists and those most common in Vermont will be described in this article.

MICA SCHIST

Perhaps no variety of this group is more widely distributed in Vermont or more easily identified than this. It is mainly composed of quartz, mica and feldspar as we have found in granite and gneiss, but usually it is not difficult to distinguish it from these. Mica Schist is a soft rock, easily decomposed, mainly because of the presence of iron oxide which often falls into powder and then the other minerals in the rock readily separate and the whole mass goes to pieces. Often as this change in the iron content goes on the black mica in which there is much iron, changes from black to bronze or yellow. Then the rock is full of little yellow scales which, as to the uninitiated they resemble gold, have deceived many, if we may judge from the very frequent samples sent to the office of the geologist. Often in digging ditches or wells sand resulting from the decomposition of Mica Schist, is found full of little scales of mica which have changed from black to yellow and thus aroused the curiosity of the finder. These scales are elastic, which gold never is and gold is never in thin scales. Mica Schist also often contains iron pyrites, which being yellow, is mistaken for gold. These minerals resemble gold only in color. The original condition of Mica Schist is either Shale, or Sandstone or more rarely Conglomerate. The materials in these rocks are very completely broken up and their elements recombined to form the minerals of the Schist.

A peculiar form of Mica Schist is found in Shrewsbury, a few miles from Rutland. This, Chrome Mica Schist, is of a very pretty green color, is very hard and does not occur in large quantity but it is interesting as a strange variety. As has been noticed Schist sometimes very closely resembles Slate, so that it may be mistaken for true Slate. I have known of cases where hundreds of dollars were spent in opening a "Slate Quarry" when there was not a foot of Slate near the locality, but only worthless Shale. Slate is to be considered later, but it may be well to notice at this point some of the differences between Slate and Shale. Slate is much more even and compact than most Shale. Slate splits in much thinner layers, and most important of all, is the direction of the layers. Slate always splits at an angle, usually a high angle, to the bedding planes while Shale splits parallel to the bedding. Schist is brittle and wholly worthless for roofing, or any other use to which Slate is put. Slate, Mica Schist and Phyllite (to be described later) are regarded as three stages in metamorphism. Slate is only to a small extent changed from the original condition. Phyllite has been more completely changed, Schist most entirely changed. Mica Schist is of little economic value, though some of the more compact beds afford very good flagging stones.

PHYLLITE SCHIST

Though less abundant in Vermont than the preceding, Phyllite is an important rock in many parts of the State. As just noticed, Phyllite may be considered as an intermediate form between Mica Schist and Slate. It is usually of dark color, splits quite irregularly, is more compact than Mica Schist. It is more common on the east side of the State than west of the mountains. Good typical examples may be collected in Newport, Coventry, Bethel, etc.

SERICITE SCHIST

This rock resembles Phyllite, but is usually lighter in color and may be identified by its very silky surface. Sericite is fine grained, compact and its silky surface is due to the presence of a large amount of mica, which is light. The mica is in very small scales. The rock also contains considerable quartz. Sericite is found in many towns, as Irasburg, Troy, Newport and south on the east of the Green Mountains through the State. This Schist is not as plainly foliated as many, the layers being often thick and irregular.

CHLORITIC SCHIST

Though not as abundant in Vermont as some of the other Schists, Chlorite is found in many of our towns. It is usually plainly foliated, of a greenish shade, often dark and there are many varieties, some of which are not easily recognized. It is to be found in Concord and other towns in the northern part of the State and from there south to Bethel, Braintree, etc.

AMPHIBOLITE

This Schist closely resembles Hornblende Schist, but the term is more inclusive and because it includes many varieties, it is not possible to describe it so that it can always be determined. It is a hard rock, of dark green or even black color and contains much hornblende. Many Amphibolites are local in distribution and have been given local names. The beginner in the study of schists will need the help of an expert in naming his specimens of Amphibolite. Schist of this kind may be found widely distributed over New England. In Vermont they are exposed in Belvidere, Norwich, Plymouth, etc.

HORNBLENDE SCHIST

The long slender crystals of black hornblende are seen in many of our Schists but they occur in greater abundance in this variety than in others. As found in Vermont, hornblende is always black or dark green, very hard, with rather dull luster and crystalline in structure. The crystals may be as large as a lead pencil, but more often they are much smaller and when closely packed, they give a silky luster to the surface of the rock. Besides hornblende, this Schist contains quartz, mica and other minerals. The collector will find this rock at Mount Ascutney, Norwich, Barnet, Lunenburg, Holland, Marlboro, Cavendish, Mount Holly, Plymouth and other towns.

The following list includes most of the varieties of Schist found in Vermont up to the present time. It is more than likely that other varieties will be named as the rocks of the State are more thoroughly studied.

As the names indicate, some of the varieties are very local in distribution, some differ from others of different name only in the greater abundance of some particular mineral, which in some measure all contain.

The writer does not intend by including a name in the list to signify his endorsement. The names are placed here because they have been used by some writer on Vermont geology. It is believed that most are "good" but a few may not long continue.

List of names of Vermont Schists as used by different authors:

Acmite Schist	Brandon
Actinolite Schist	Goshen, Rochester
Albite Schist	
Amphibole Schist	Norwich, Bethel, Eden, etc.
Berkshire Schist	Castleton, Hubbardton
Bethel Schist	Bethel
Biotite Schist	Ripton
Bradford Schist	Bradford
Chlorite Schist	Braintree, Halifax, etc.
Chrome Mica Schist	Shrewsbury
Epidosite Schist	Bethel
Gôshen Schist	Goshen
Halifax Schist	Halifax
Heartwellville Schist	Heartwellville
Hornblende Schist	Norwich, Bethel, etc.
Hydromica Schist	Roxbury, Braintree
Lunenburg Schist	Lunenburg
Memphremagog Schist	Orleans County
Mica Schist	Through the Green Mountain Region
Orleans Phyllite	Willoughby Region
Phyllite Schist	Coventry, Newport, many localities South
Pinney Hollow Schist	Plymouth
Quartzite Schist	Many localities
Readsboro Schist	Readsboro
Sericite Schist	Many localities

Staurolite Schist	Springfield
Talc Schist	Johnson, Moretown, etc.
Tourmaline Schist	Strafford, etc.
Whitingham Schist	Whitingham
Woodstock Schist	Woodstock

I would again remind the reader of the above list that no attempt is made to give other than a few of the localities where the rock may be found so that he should not infer that because the kind he looks after is not mentioned as found in a particular town it may not be well exposed there. As already stated, to give a complete list of localities would require a great deal of space, more than can be allowed.

A few other species of Metamorphic Rocks should be mentioned. These are Slate, Marble, Quartzite.

SLATE

The likeness and unlikeness of Slate and Shale have already been noticed, but somewhat may be added to what has been written. One is Sedimentary in origin, the other Metamorphic. Shale splits with the bedding plane of the rock. Slate is always laminated at a high angle to the bedding plane because the pressure under which Slate is formed, much of it at least, was exerted not directly upon the hardening mass, but at the ends. When there was pressure on Shale it was usually simply from overlying deposits, pressure in forming Slate was because of folding, or some other movement of the earth crust. It may be imitated by placing layers of clay in a stout box and applying pressure at a movable end. If this pressure is great enough, the material of the mass is supposed to be changed in structure. That is, the particles contained are so flattened that the planes of cleavage are at right angles, or approximately so, to the direction of the pressure. On account of this change the mass splits in thin layers, or laminæ. "Slaty cleavage is partly molecular, when it passes through a single mineral particle, and partly mechanical when it passes between arranged or unlike particles. The cleavage planes do not necessarily bear any definite relation to those of the original bedding. . . . But as the beds may be folded before the pressure becomes intense, the cleavage may pass through the bedding at various angles."[1] The structure of a slaty mass is by no means as simple as the illustration given above, but, allowing for irregularities, it may be allowable to assume a mass composed of, or at least containing, multitudes of little spherical bodies. If great pressure is applied to such a mass the spheres will be likely to be flattened and made oval, all with the long axis, in a direction perpendicular to the direction of the force. It is easy to understand that a rock having such arrangement would naturally split in ac-

[1] Pirsson Textbook of Geology, p. 322.

cordance with the long axis of the component parts. This is slaty cleavage, fully developed in Slate, and partly in Shale. To the pressure is due the toughness of Slate and its close grain. It may be added to this that the chemical composition of Slate is much more simple than that of most Schist. Shale, too, is simpler than Schist. Slate is not as common or widely distributed as either Schist or Shale. Good roofing Slate is found in only a few of the states. Vermont supplies the market with more than any state except Pennsylvania. In color Slate is most commonly black, or very dark gray, though in Vermont it is often green, purple or mottled. Just over the state line in New York quarries of red slate are worked, but though at times the western border of Vermont is within a short stone's throw of a deposit of red Slate, not a bit is quarried in this State. All slate quarries now worked, and there are many, are in Rutland County and on the western border of the State. Slate deposits that have been worked at one time or another are in Thetford, Montpelier and especially Northfield.

MARBLE

While some of the "Marble" sold in really unchanged Limestone, as the black "Marble" of Isle La Motte, the gray of Chazy, New York, true Marble is Metamorphic rock. All of the Vermont Marble is of this sort except a very few kinds. The Marble of Vermont has been famous all over the world for many years, and now this State produces far more than any other area of like size. A full account of "The Marble Industry of Vermont" was published in the Ninth Report of the State Geologist (1913-14). While this volume has for a long time been out of print, it may be found by any who wish to study this subject in many libraries. True Marble is metamorphosed limestone. Probably most of the limestone was fossiliferous, but in nearly all deposits, the transformation from limestone to marble has completely obliterated these proofs of ancient life. Near the bottom of the old Ripley quarry at West Rutland large fossil coiled shells have been found so well preserved that they are easily recognized by geologists. By these, which fortunately, are characteristic fossils, the age of the marble is definitely determined. Pure white marble is calcium carbonate, but most of the many varieties found in Vermont contain impurities, iron, manganese, chlorite, carbon, and many other minerals. These fortunate impurities, as they are mixed in varying proportions produce the different varieties. I suppose that the Vermont Marble Company could from different quarries supply a hundred varieties if they were called for by trade. Usually, however, not half this number are desired. Marble does not split in laminæ like Shale, and is usually crystalline in structure. Using trade names, Vermont "Marble" is of several differ-

ent geological ages. All the true Marble, that of West Rutland and adjacent places is lower Ordovician, the "Champlain Marbles" of Swanton are lower Cambrian and the "Roxbury Marble" is a Serpentine and probably still older. All of the more valuable commercial Marbles of Vermont are located in the western part of the State, mostly in Rutland County, though there are outcrops of very impure marbles east of the Green Mountains. None of these is used in the trade.

QUARTZITE

Sometimes an ordinary Sandstone becomes saturated with a solution of silica, so that the separate grains of sand of which it is composed are as if fused together and when broken the break runs through the grains, rather than, as in Sandstone, between them. Then the Sandstone has become Quartzite. This rock is very common, especially west of the Green Mountains. In some masses, Quartzite differs little from Sandstone while elsewhere it has been more fully metamorphosed and, besides silica, which is always predominant, it contains other minerals, as mica, feldspar, etc. Our Quartzite is usually of a grayish color, but it may be white or some shade of red. Quartzite is classed with Metamorphic Rocks, but it may be very little changed from its original sandstone. In one locality there may be a very solid, compact Quartzite, while in another, not far away, perhaps, there are layers much less compact and these may be followed by typical Sandstone.

In conclusion the writer wishes to commend the study of Vermont geology which has been undertaken in a number of our High Schools and to urge other schools to do likewise. Such study, especially if accompanied by field work, cannot fail to produce excellent results. Let the scholars in each school begin by collecting specimens of rocks which are found nearest the schoolhouse. Study these different kinds and name as many as possible, using the characters given in this article, if no work which may be more full and helpful is to be had. The State Geologist will always be ready to help in any way possible and will gladly examine and as far as possible name any specimens or collections that are sent to his office in Burlington. Typical specimens should be chosen, those that are not weathered nor worn; pieces three or four inches square and not very thick, say not much more than an inch or two, will be large enough. Do not, as has been done more than once, collect a lot of pebbles from some bank of gravel. They are most likely to be difficult to identify and often will not be Vermont stones, but of glacial origin and therefore from the north, it may well be, a long distance north in Canada. Of course such stones have no place in a collection of Vermont rocks.

A brief list of Works on Granite, Marble and Slate is added. Most of the books in the list should be found in any of the larger libraries.

GRANITE

"Granites of Vermont," T. N. Dale, Bulletin U. S. Geological Survey, No. 404, 1909. Reprinted in Report Vermont State Geologist, 1910.

"Commercial Granites of New England," T. N. Dale, Bulletin U. S. Geological Survey, No. 738, 1923.

"Granites of Bethel, Barre and Woodbury," Robert Balk, Report Vermont State Geologist, 1927, pages 39-96.

MARBLE

"Marbles of Western Vermont," T. N. Dale, Bulletin U. S. Geological Survey, No. 521, 1912.

"Calcite Marbles and Dolomite of Eastern Vermont," T. N. Dale, Bulletin U. S. Geological Survey, No. 589, 1913.

"History of the Marble Industry of Vermont," G. H. Perkins, Report Vermont State Geologist, 1914, pages 1-276.

In this article the Bulletins of T. N. Dale are reprinted.

SLATE

"The Slate Belt of Eastern New York and Western Vermont," T. N. Dale, Nineteenth Annual Report, U. S. Geological Survey, Part 3, 1899.

"Vermont Slate," Report Vermont State Geologist, 1906, pages 89-120.

"Slate in United States," T. N. Dale, Bulletin U. S. Geological Survey, No. 281, 1914.

In all of the biennial Reports of the State Geologist more or less is published on the building stone named above. Copies of these Reports should be found in school libraries and most of the town libraries in the State. If they are not in these libraries, copies of all the volumes not now out of print can be obtained without cost from the State Librarian, Montpelier, Vermont, by any of the libraries in the State.

If possible it is the writer's intention to publish in the next Report a list of the Minerals of Vermont with brief description of each species.

THE PETROGRAPHY OF THE IRASBURG CONGLOMERATE

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The Irasburg conglomerate was discovered in Irasburg, Orleans County, Vermont, during the summer of 1904. When I announced this discovery, I was told that such a conglomerate did not exist and could not exist because there was no erosional unconformity between the Cambrian and Ordovician terranes in New England. The discovery site is in the bed of Lords Creek just outside the southern limits of the village of Irasburg. Another excellent exposure of this conglomerate is about one-fourth mile south of the village of Irasburg and on the east side of the main road to Albany. This outcrop is further located by a large isolated pre-Ordovician boulder weighing nearly 100 tons and within 10 rods of the main road from Irasburg to Albany. A few boulders, some of them six inches in diameter, were found one-half mile west of the village of Irasburg. The area exposed in the township of Irasburg is about four miles in length and one-half mile in width in the widest part.

Accurate measurements of the dip and strike of this terrane are attended with great difficulty for the strike sometimes changes 90° in 10 feet. The general strike, however, is north 40° east. The dip through complex folding appears in all directions and at all angles. In general the dip is to the west but further south, as in the Eligo Valley in Hardwick, the dip is to the east. The entire conglomerate is highly crumpled and folded. The planes of schistosity do not pass through the pebbles and boulders, but around them.

In some parts of this conglomerate the pebbles are small and well water worn. Sometimes the longer diameter is three or four times the length of the shorter diameter, sometimes the pebbles are faceted as if by glacial action and in a few instances striations have been observed. Boulders varying from one foot to two feet in diameter are not uncommon. These suggest either a shore conglomerate or else one of glacial origin, or possibly both.

When this conglomerate was discovered it was supposed to be a more or less local phase of the Waits River limestone. Such is not the case. The conglomerate has been followed to the northward into Canada for 200 miles, and southward through Vermont for more than 100 miles. Much of the area is drift covered and often wooded so that a continuous outcrop cannot be traced.

The Irasburg conglomerate or its time equivalent can be divided into five more or less distinct phases.

1. The Irasburg phase.
2. The Albany phase.
3. The Northfield phase.
4. The Coventry phase.
5. The Magog, Quebec, phase. (J. A. Dresser.)

In all phases of this time marking terrane the matrix is all of Ordovician age although it varies widely in chemical and mineralogical composition. It is proved to be Ordovician by its fossil content. Several species of graptolites have been identified in it by Dr. Rudolf Ruedemann, State Paleontologist, Albany, New York. In general the matrix is a siliceous limestone or a quartzose marble which consists of well rounded quartz grains and calcium carbonate, often well crystallized as calcite. It carries a few plates of muscovite and biotite which are characteristic of the Waits River limestone series. Uncombined carbon is the cause of the dark gray color. In the Northfield phase the matrix is slate.

In each phase the pebbles and boulders are of pre-Ordovician age. They have been derived from the Cambrian terranes that flank the conglomerate on the west or else they have been brought in by a pre-Ordovician glacier, or possibly by both. That some of the boulders have been derived from the Cambrian sediments directly west of the conglomerate is fairly well established, but the original source of some of the pebbles and boulders of igneous origin has not been proved. They may have been brought down from Megantic County, Quebec, in a southwesterly movement of a pre-Ordovician ice sheet. Igneous rocks of the same composition as these boulders are known to exist in Megantic County.

The clastic pebbles and boulders consist of sericite schists, micaceous quartzites, sericitic marble and chlorite schists probably of sedimentary origin. All of these are found within reasonably close proximity to the various outcrops of the conglomerate. The Cambrian sericitic marble has been found only in the Albany phase. A few pebbles of a medium textured muscovite schist were found in this conglomerate in Craftsbury in the Eligo Valley.

The pebbles and boulders of igneous origin consist of vein or dike quartz, either hydrothermal or the final product in solidification of an acid magma. Some of these are a foot or more in diameter and perfectly smoothed like the one found in Albany in 1915 embedded in limestone. Several granite boulders have been observed in Irasburg. The largest one nearly a foot in diameter is only about 10 feet from the large glacial boulder above mentioned. A microscopic slide of a granite pebble in this outcrop showed as essential minerals quartz, orthoclase, muscovite and biotite. A few grains of microcline, a little albite to albite-oligoclase, and a few small apatite grains were found. Porphyritic andesite boulders are present in both Albany and Irasburg. In earlier reports these were listed as porphyrites. Several of these have been obtained from the south side of Lords Creek in Irasburg and many have been found in Albany in the cut in the road leading from West Albany to Craftsbury Common. Microscopic slides of these boulders have shown phenocrysts of orthoclase and microperthitic feldspars in a finely crystalline ground mass consisting of a fine felt of little rods of feldspars, and a few small grains of ferromagnesian minerals. Diorites whose essential minerals are andesine and hornblende have been found in both Irasburg and Albany, although some of the plagioclase feldspars are now richer in sodium than andesine. Diabases or basalts with ophitic texture have also been found both in Irasburg and Albany. Serpentine appears in Albany, apparently derived from the alteration of peridotite, but other rocks rich in ferromagnesian minerals can produce serpentine. There are also pebbles present that approximate in composition to albitite. The feldspars are more or less ophitic in texture and there is a great paucity of the ferromagnesian minerals. In the Northfield phase devitrified rhyolites are present. Phenocrysts of orthoclase appear in a felsitic ground mass of very minute quartzes and feldspars which still show the flow structure of the original rhyolite.

These various types of pebbles and boulders cannot all be found in any one locality. The Irasburg phase is characterized by boulders more than two feet in diameter, by porphyritic andesites and by granite boulders. The Albany phase is characterized by the presence of Cambrian marble, by porphyritic andesites, more than a foot in diameter, and by large well smoothed boulders of pure quartz. The Northfield phase is characterized by pebbles of devitrified rhyolite embedded in a paste of clay slate. In this slate Dr. Rudolph Ruedemann has identified the species Phyllograptus augustifolius which indicates the Deepkill shale (Beekmantown).

The Coventry phase is markedly different from any of the others. It is characterized by well rounded, smoothed, sometimes faceted and sometimes apparently striated boulders of pure white quartz which vary in size from an inch up to a foot in diameter. Fragments of Cambrian schists sometimes more than a foot in diameter and set at right angles to each other are embedded in an Ordovician paste of limestone and slate. Sharp angular fragments of slate are at times found embedded in the paste of limestone. It is the author's belief that this rock represents a fault-breccia conglomerate. Even post-glacial faults are known to exist in the Ordovician slate in Albany. This breccia-conglomerate is located about 10 miles north of Craftsbury near the contact of the Cambrian and Ordovician terranes. The main road from Newport to South Troy passes over this terrane. The Magog phase was discovered by Prof. J. A. Dresser.[1] Its pebbles are pre-Ordovician and its matrix is Ordovician. It lies at the base of my Memphremagog slates. In this respect it conforms to the Northfield phase which is more than 100 miles further to the south.

CONCLUSIONS

The Irasburg conglomerate in its different phases must be a time marking terrane in Eastern Vermont. Since the matrix is all Ordovician and the fossil content Lower Ordovician sedimentation began as early as the Beekmantown.

Since the pebbles and boulders in the conglomerate are all of pre-Ordovician age they were probably derived from the various Cambrian terranes that flank this conglomerate on the west. Some of them are definitely known to have been derived from these formations. Some of them may have been derived from even pre-Cambrian formations. The presence of granite boulders would suggest this for the time element would hardly be sufficient for the erosion of Cambrian sediments to Cambrian granites in Early Ordovician time. The actual source of the boulders of igneous origin is unknown. Glaciers could have brought them from Canada. Detailed field work on the Cambrian terranes to the west of the conglomerate may prove the source to be in the eastern foothills of the Green Mountains in northern Vermont.

The terranes to the west of the conglomerate must be of Cambrian age for the basal member of this series of great thickness is the Sherburne conglomerate whose matrix is all regarded as Cambrian and whose pebbles and boulders are all pre-Cambrian schists, quartzites and gneisses of Algonkian age. If they are not Algonkian then sedimentation began along the axis of the Green Mountains in Archean time and the injection into these sediments of acid and basic intrusives came at the close of the Archean. There is no positive evidence that such an early chapter was written in the geologic history of Vermont.

[1] The Magog conglomerate, a horizon mark in the Quebec Group, J. A. Dresser, 1925.

THE TOPOGRAPHIC MAPS OF VERMONT AND LIST OF ALTITUDES

Topographic Maps of Vermont Quadrangles, Published by the United States Geological Survey in Cooperation with the Vermont Geological Survey

GEORGE H. PERKINS

CONTENTS

PREVIOUS PUBLICATION OF ALTITUDES

On the following pages the writer wishes to explain the work of the United States Geological Survey in Vermont and its cooperation with the State Geological Survey in making a thorough and accurate survey of Vermont and from the data they obtained publishing a series of Topographic Maps which are to cover the entire area of the State. As will be shown below, this work is well towards completion, most of the area of Vermont being now surveyed and nearly all mapped. Those who are familiar with the contents of previous Reports may notice that a considerable portion of the following lists have been printed in these former volumes. They are repeated here for several reasons.

Several volumes of the older Reports have been out of print for some time, and all the remainder were so damaged by the flood at Montpelier, where they were stored, that they are unfit for use. As a result of increased appropriation by recent Legislatures the work of surveying has been carried forward much more rapidly than was formerly possible and by this means large additions to the lists already published are now available, also several important corrections of errors in the old lists are here made in the altitudes given. Because of these facts, and there are other reasons, it seems to the writer best to begin and develop this article as if no others had been published. From what has just been written it is obvious that the following lists must replace all that have preceded. It may be added that eighteen of the older maps have been reprinted by the Federal Survey and some important changes have been introduced.

DESCRIPTION OF THE MAPS

Those who have used any of the new Topographic Maps do not need to be told how far superior thees maps are to maps of any part of the State heretofore published. In what follows the writer will attempt to show in detail what these improvements are. It is sufficient here to call attention to the fact that the expense of collecting the details and publishing the results of such survey as that of the United States which for some years has been carried on in Vermont, as well as in many other states, is so great that without the cooperation of the Federal Survey such maps would not be possible.

If one using the maps will be at the trouble to study them carefully, aided by explanations given on the back of each sheet, he will be surprised by the many details represented. The very many facts which one may learn from these maps may at first be confusing, but careful study will soon make full understanding easy and very useful. As all the maps of Vermont made by this Survey are made on the same plan, when the symbols, etc., used are once learned this knowledge can be used in reading all.

Each sheet on which the maps are printed is called a "Quadrangle." The quadrangle varies as to the area covered according to the latitude of the part mapped as each map is made to cover 30′ (thirty minutes of latitude and the same of longitude.) They are on a scale of 1/62,500. While this is not exactly one mile to an inch, it is near enough for ordinary purposes so that unless one needs a very exact measure he may calculate distances by this measure, *i.e.*, one mile to the inch, whether he wishes to know the distance from one point to some other along a highway or across country. A comparatively small number of maps are made on a different scale for special reasons, but only two of these are Vermont maps (the Metawee and the Taconic) and the same territory is also covered by maps on the ordinary scale. The usual area of a quadrangle varies from two hundred and twelve to two hundred and twenty square miles and the size of each sheet is sixteen and a half inches wide by twenty inches long. Different features in any quadrangle are indicated by fixed symbols which are the same on all maps and explained on each map; features such as mountains, hills, streams, swamps, canals, brooks, forests, roads, lakes, ponds, etc. On the later maps not only are all roads shown, but the quality of each is noted, as the best highways are indicated by double lines, fairly good roads, though not

of the best, are shown by finer double lines, while poor and little used roads are shown by broken lines (double), and trails by single dashed lines. Of course on maps of the size of the quadrangles individual buildings, houses and public buildings, cannot be named, but as little black rectangles all are indicated, school houses by little flags. Difference in elevation above sea level is shown by "Contour Lines." These are found on no other maps. "A Contour Line represents an imaginary line on the ground every part of which is at the same altitude above sea level." These lines are very conspicuous on all the maps, always printed in brown. On the Vermont maps these lines are twenty feet distant and every hundred foot contour is made heavier. Moreover at many fixed points definite figures are printed.

As each quadrangle is necessarily rectangular and few of the Vermont towns are regular, it follows that in many cases towns, or group of towns, do not coincide with the boundaries of a single map. It is inevitable that many towns will be partially shown on one quadrangle and part on another adjoining, or more rarely, a town is so situated that parts are shown on several maps. Because of this a Table is here given which shows on which quadrangle or quadrangles each town is displayed.

USES AND VALUE OF THE MAPS

The practical value of the maps has already been mentioned, but additional points may be noticed. Highways, trolley lines, canals, mill races, reservoirs, any public construction when it is necessary to know the different levels to be crossed. Also the general character of the surface of large areas and the elevation above sea level of towns, hills, mountains, etc. I can give here only one of many instances which illustrate this.

Not many years ago, I heard in a talk by the Highway Commissioner of one of our largest counties that as it had been decided to construct a new road for several miles in his county he employed an engineer to lay out and survey the road. It occupied this engineer two weeks to accomplish the task and the desired road was made, very considerable expense being involved. Later, when the topographical map of this region was completed this Commissioner stated that he had looked it over carefully and he was convinced that if at the time the road was made he had been able to use the new map he could by an hour's study in his office have laid out a better road, and of course have saved a good deal of money.

I quote this incident, and as has been noticed many others of similar import are at hand, to show that all the cost of these maps should be regarded as an investment which is sure sooner or later to produce large dividends. Although the immediate cost of the necessary surveys, etc., may seem considerable there is no doubt that in the long run this cost will be much more than returned to the State.

COOPERATION IN MAPPING

I have spoken of cooperation in the preparation of the maps. By "Cooperation" is meant the arrangement which the Federal Government makes with cooperating states in paying for this work. By this arrangement the Government bears considerably more than half of all expense. The work is done by the experienced engineers of the United States Government, experienced as no other engineers are likely to be in this kind of work; the drawing, engraving, printing required are done by Government experts and when finished, the maps are sold to anyone who wishes them at a uniform price, about cost, as shown later.

To illustrate—this or some other state appropriates a certain sum annually for the cooperative survey and the General Government meets this by an equal sum, then most of the cost of producing the maps is met by the General Government. In this way the State of Vermont is getting far better maps than have before been possible at a cost of from one-third to one-half of their value. It is scarcely necessary to add that the State alone could not or at least would not meet the cost of such maps. Moreover, once made no others will be needed for a great many years.

It may be well to call the attention of the people of Vermont to their good fortune in securing their survey at this time and, as will appear later; nearly the whole area of the State is now surveyed. It is good fortune because since the survey of the State was commenced the cost of such work has greatly increased so that what has been accomplished has cost much less than it would cost now, and also because other and larger states are clamoring for cooperation and offering very much larger appropriations than Vermont can afford, so that if the State had not begun cooperation when it did the chance is that it would have had to wait till after some of the larger and more wealthy states had been surveyed.

Of course, the size of the territory surveyed depends wholly on the size of the appropriation made and some of the states have pledged ten times the amount which Vermont has ever paid. This too when Vermont because of its irregular surface is one of the most difficult and therefore expensive areas to survey that is to be found in the whole country. Residents of this State do not need to be told that it is very hilly and often mountainous. Such a surface as that of Vermont can be accurately and thoroughly surveyed only at much cost. It is easily understood that this very feature of our surface makes it the more important that to be of real value, a survey be thorough and accurate. This as well as small appropriation has been a reason why the survey we are considering has been slow, as the following history of the work will show.

A condensed History of the Vermont survey cannot fail to be interesting.

HISTORY OF THE TOPOGRAPHICAL SURVEY

It may be a surprise to some who read this to learn that the Topographical Survey of this State was begun more than thirty-four years ago. For some years the survey was carried on very quietly and comparatively few of our residents knew anything about it, and during the first years there were numerous periods when it was not carried at all. When the State began to appreciate the real value of the survey and made a small appropriation in its aid the work went continuously forward, is still going on and, as we have seen, is near completion.

The first maps were issued in 1894. A number of the earliest maps were not made by the aid of Vermont, but by New York. As shown above each map is a "Quadrangle." The state of New York began mapping long before it was taken up in Vermont. When the eastern border of New York was reached all "Quadrangles must be carried over Lake Champlain into Vermont. Some of these included a considerable area in Vermont, others very little but all covered the eastern shore of the Lake and more or less of western Vermont. In this way the entire western edge of this State was surveyed and mapped without any cost to Vermont. Of this group of maps are the Rouses Point, Plattsburg, Port Henry and other maps.

Though of much less area covered, the northern tier of Massachusetts maps extend north into Vermont. These include southern parts of such towns as Halifax, Vernon, Stamford. All these maps were made before 1896. Several other maps located in different parts of Vermont were also made without cost to the State, as Strafford, Rutland, Brattleboro. Several "Quadrangles" in the eastern border, along the Connecticut River, have been made in cooperation with New Hampshire and the Federal Survey, and a few more are yet to be made. These, as Hanover Quadrangle, Claremont, etc., include in part Vermont, in part New Hampshire.

Vermont has been greatly aided in the mapping by the War Department, as during the last few years, a series of six maps completing the Canadian Border have been made, the last of these being issued in 1927. By these statements it appears that Vermont has been very fortunate in receiving a not inconsiderable amount of aid in mapping the whole State.

In 1910, many States applied to the Federal Government for aid in securing topographical maps of their territory offering larger appropriations to meet the Government appropriations. As a result of this, the Federal Survey decided that no further maps could be made, unless the national appropriation was met by one from the states desiring a survey. On this account the State Geologist of Vermont was notified that no further surveying would be undertaken in this State unless the State Legislature appropriated a sum for cooperation with the Federal Survey.

After several attempts to obtain such appropriation from preceding sessions, in 1913 the Legislature of that year appropriated two thousand dollars annually in aid of the project. After a few years this amount was increased to three thousand dollars annually and in 1927 to five thousand. As about a third of the State had already been mapped, as shown above, these appropriations though small, as compared with those of other states, have been sufficient to accomplish the work of surveying and mapping most of the State. Up to the present time, 1928, fifty "Quadrangles" have been surveyed and most of them will have completed maps by the time this volume is published. Of the maps published forty are wholly or very nearly so, within the boundaries of the State, while the remainder include parts of Vermont and parts of adjacent states. When the entire State is covered rather more than sixty maps will be made. It should be noted, however, that several of these contain so very little of Vermont territory that they are of little or no use, as far as Vermont is concerned. This may seem to some a large number of maps to cover as small a territory as that of our State, but I am sure that after using any of them, no one will find the scale too large.

SUMMARY OF THE QUADRANGLES

In order to make this paper as convenient as possible when used in ascertaining facts concerning a particular town the following list has been prepared by means of which the map, or maps, on which the town is displayed is named, the Quadrangles being arranged in order from west to east, and from north to south. As in some cases it is necessary to know the date of the map used, as changes are sometimes made in the latest map issued, the dates of the maps are given. Anyone using the maps should be sure that he has the latest issued. In a very few cases, maps have not been included in the following list, as they include nothing of importance in Vermont.

LIST OF QUADRANGLES IN WHICH ANY PART OF VERMONT IS SHOWN

Rouses Point Map, 1895

About half of the Rouses Point map is occupied by Vermont. Starting at the Canadian border it includes, in Vermont, most of the Alburg Peninsula, all of Isle La Motte, all of North Hero, the northern end of Grand Isle and the north end of Lake Champlain.

St. Albans Map, 1916

This map includes nearly the whole of Highgate, all of Swanton, all of St. Albans, a small area in the west of Sheldon, the north part of Georgia, northwest part of Fairfax, a little of West Fairfield, the east end of Alburg, the north end of North Hero and a part of Lake Champlain.

Enosburg Falls Map, 1926

This map is the first of the series extending from the St. Albans map to the Connecticut River across the northern border of Vermont. As has been stated this series was made at the request of the War Department. The towns shown on this map are as follows:—all of Franklin, most of Sheldon, the west part of Berkshire, the east part of Highgate, west part of Enosburg, nearly the whole of Fairfield, most of Bakersfield, a bit of the northwest corner of Waterville, and a very small area in the north of Fletcher.

Jay Peak Map, 1926

On this map is included all of Richford, all of Montgomery, all of Averys Gore, Franklin County, the east part of Berkshire and Enosburg, northeast corner of Bakersfield, a large area in the north part of Belvidere, the north part of Eden, the west part of Lowell, west part of Westfield and Jay.

Irasburg Map, 1926

The whole of this map is in Orleans County. It covers the towns of Troy, most of the township of Newport, but not the City, a large area of the east part of Jay, the eastern part of Westfield, much of Lowell, the west part of Irasburg, north part of Albany, west part of Coventry.

Memphremagog Map, 1926

On this map is the city of Newport and much of the town, the whole of Derby, the west part of Holland, most of Charleston, the west part of Morgan, Westmore, most of Barton, the whole of Brownington and the west part of Coventry.

Island Pond Map, 1926

This map includes all of the Averys Gore (Franklin County), all of Warrens Gore, Charleston, some of the east part, nearly the whole of Brighton, the east part of Holland, most of Norton, the east part of Lewis, the east part of Morgan, east part of Westmore, north part of Newark, northwest part of Ferdinand, all of Island Pond.

Averill Map, 1927

This is the last of the maps made for the War Department. It covers the extreme northeastern part of Vermont and its southeastern area takes in a small portion of New Hampshire. The Vermont towns included are: the whole of Averill, the whole of Lemington, all of Bloomfield, all of Canaan, the eastern part of Lewis, north part of Brunswick, northeast part of Ferdinand, east part of Norton, all of Averys Gore (Essex County).

Plattsburg Map, 1894

In Vermont this map includes nearly all of Grand Isle, all of South Hero, the northwest point of Colchester, a little of northwest Burlington, and a large part of Lake Champlain.

Milton Map, 1915

On this map one finds on the west a considerable area of Lake Champlain, most of the town of Georgia, most of Colchester, a large part of Essex, the west part of Westford, the west part of Fairfax, and a little of northeast Burlington, all of Milton.

Mount Mansfield Map, 1927

On this map is a little of the south part of Fairfield, the south part of Bakersfield, west border of Waterville, east part of Fairfax, most of Cambridge, east part of Westford, nearly the whole of Underhill, west part of Stowe, north part of Jericho, a little of northeast Essex, nearly all of Fletcher, and the southwest corner of Morristown.

Willsboro Map, 1895—Reprinted 1898

This map is mostly in New York. It includes a large area of Lake Champlain and the western border of the Vermont towns—Shelburne and Charlotte and a small bit of Ferrisburg.

Burlington Map, 1906

This map covers nearly the whole of Burlington, Williston, Shelburne, and Hinesburg, most of Charlotte, most of Richmond, a little of Essex, including Essex Junction, western part of Jericho, and Huntington, north end of Ferrisburg, Monkton, and Starksboro, south part of Colchester, including Winooski.

Camels Hump Map, 1924

This sheet covers a large part of Jericho, south part of Underhill, west part of Stowe, the whole of Bolton, the whole of Duxbury, a large part of Huntington, northeast corner of Starksboro, north end of Fayston, a bit of west Moretown, a large area in Waterbury, the eastern part of Richmond.

Montpelier Map, 1921

On the Montpelier map are—much of Stowe, all of Montpelier, all of Middlesex, all of Worcester, the north part of Moretown, a large part of Elmore, the west part of East Montpelier, northern part of Moretown, east part of Waterbury, a little of south Morristown, west part of Calais, a little of the north part of Berlin.

Ticonderoga Map, 1896—Reprinted November, 1908

This New York sheet includes, besides a good bit of Lake Champlain, a large area in Vermont. Of the Vermont lake towns there are here found nearly all the area of Bridport, Shoreham and Orwell, and a narrow strip of the north border of Benson, and a very narrow strip of western Cornwall.

Brandon Map, 1904

On this map is found the whole of Brandon, Salisbury, Whiting and Sudbury and Leicester, the southern part of Middlebury, western part of Cornwall, western part of Ripton, west part of Goshen, a little of the east edge of Shoreham, more of Orwell, a bit of Pittsford, a little of the west border of Chittenden, and just a bit of the northeast corner of Benson.

Rochester Map, 1917

On this map may be found the whole of Hancock, nearly all of Chittenden, Pittsfield, and Rochester, northwest part of Stockbridge, east part of Goshen, east part of Ripton, west part of Braintree, south part of Granville, a little of southwest Bethel.

Randolph Map, 1926

On this map we have the southeast part of Braintree. the whole of Randolph, the southeast corner of Braintree, a little of southwest Chelsea, the northeast corner of Rochester, nearly all of Bethel, the west part of Tunbridge, nearly all of Royalton, a little southwest corner of Sharon, the north part of Barnard, and the northeast part of Stockbridge.

Strafford Map, 1898—Reprinted 1899

This map includes a large area in the north of Sharon, the whole of Strafford, west part of Thetford, most of Vershire, east part of Tunbridge, southeast of Chelsea, southeast corner of Corinth, southwest of Fairlee.

Whitefield Map, 1900

Most of the territory covered by this map lies in New Hampshire, but there is a little in Vermont, which includes a large area in Lunenburg and a small one in Guildhall.

Port Henry Map, 1898—Reprinted March, 1901

Although this map was made by New York, more than half is occupied by Vermont territory. Besides a large area of Lake Champlain, there is a wide strip of the western part of Ferrisburg, also of Panton, covering the entire town, all of Addison, the north end of Bridport, the northwest corner of Weybridge, a narrow strip of Waltham, and a little of Vergennes.

Middlebury Map, 1905

The Middlebury map includes the whole of New Haven, the whole of Bristol, the north portion of Middlebury, most of Weybridge, a large area in Ferrisburg, much of Monkton and Starksboro, the western part of Lincoln, eastern part of Waltham, northwest part of Ripton, a little of north Cornwall.

Lincoln Mountain Map, 1921

This map covers several mountain towns as—all of Warren, most of Fayston, a large part of Granville, most of Waitsfield, the eastern part of Lincoln, the northeast part of Ripton, west part of Roxbury, a strip of eastern Starksboro, the south point of Huntington, a little of west Northfield, a bit of Moretown, and a very small bit of Duxbury.

Barre Map, 1924

Most of Barre Town and all of Barre City is found on this map, also the north end of Braintree and that of Brookfield, the west border of Chelsea, nearly all of Roxbury, most of Northfield, most of Williamstown, most of Berlin, the south part of Moretown, a little of Montpelier, and of the south border of East Montpelier, and of the east border of Waitsfield, a large area in the eastern part of Tunbridge, the southeastern part of Chelsea, a little of south Corinth, and of West Fairlee, the western part of Thetford, a large part of Sharon, the north part of Norwich, a little of east Royalton.

Whitehall Map, 1898—Reprinted 1901

This map includes much of the area between Lake Champlain and Lake George in New York and the southern end of Lake Champlain. The Vermont towns covered are—nearly the whole of Benson, all of West Haven, the western part of Fair Haven, including the village.

Castleton Map, 1897—Reprinted 1900

This map covers all of Castleton, all of West Rutland, nearly all of Ira, nearly all of Poultney, a large part of Pittsford, all of Proctor, the north end of Middleton, northwest part of Clarendon, most of Hubbardton, a very little of east Fairhaven, more of east Benson.

Rutland Map, 1893—Reprinted 1898

This map includes the city of Rutland and the east part of Rutland town, the northeast corner of Clarendon, a large part of Shrewsbury, a small part of western Plymouth, the whole of Mendon, a large part of Sherburne, the southwest part of Stockbridge, a large area in southern Chittenden, the southeast corner of Pittsford, and a little of Pittsfield.

Woodstock Sheet, 1913

On this map is nearly all of Woodstock and Bridgewater, a large area in Plymouth, and Reading, a little of West Windsor, a large part of Pomfret, much of Barnard, a little of southwestern Hartland, the northeastern part of Sherburne, southeastern part of Stockbridge.

Hanover Map, 1908

Most of this map is in Vermont, though its area crosses the Connecticut River and takes in a smaller area in New Hampshire. The Vermont towns are—the north parts of Windsor and West Windsor, most of Hartland, all of Hartford, the eastern part of Pomfret, southern part of Sharon and of Norwich, a little of the east part of Woodstock.

Fort Ann Map, 1901

So little of Vermont is covered by this map that it is scarcely worth while to mention it in this list. The map includes in this State only a very narrow strip, less than a mile wide at most, and this only at the extreme south end. From here it narrows to nothing near the north end. There are no named topographic features shown along the New York boundary.

Pawlet Map, 1892—Reprinted 1912

The Pawlet map covers nearly the whole of several towns, but the complete area of none except Tinmouth, all of which is shown. On the south there is a large area of Rupert, and also of Dorset, then there are large parts of Pawlet, Danby, Wells, Poultney, Middleton, smaller parts of Ira, Clarendon and Wallingford.

Wallingford Map, 1893—Reprinted 1898

On this map is the whole of Mount Tabor, most of Mount Holly, nearly all of Wallingford, nearly all of Weston, the north part of Peru, north part of Landgrove, a narrow strip of the east of Danby, also of Dorset, south part of Clarendon, and Shrewsbury, the southwest corner of Ludlow, and the west a narrow strip only, of Andover.

Claremont Map, 1927

The Connecticut River, as shown on this map, divides it into east and west parts, New Hampshire and Vermont. Considering only the west part of the map we find the towns as follows: Nearly all of West Windsor, all of Windsor except a narrow strip on the north, nearly the whole of Springfield, and nearly all of Weathersfield.

Cambridge Map, 1898

Alhtough nearly the whole of this map is covered by New York towns, there is a narrow strip of the western border of Vermont which occupies a little of the eastern edge of the sheet. There is nothing of much importance shown in this portion of the map. It is nowhere more than a mile wide and the north end is only half this. The Vermont territory here shown is in the towns—Shaftsbury, Arlington, Sandgate and Rupert.

Equinox Map, 1900—Reprinted 1921

This map shows the whole of Manchester, the whole of Sunderland, all of Arlington and Sandgate, except the narrow strip mentioned in the preceding paragraph, the northeast part of

Shaftsbury and the north end of Glastenbury, also the south part of Rupert and Dorset.

Londonderry Map, 1899

On this map are to be found, all of Winhall, all of Jamaica, all of Stratton, practically nearly all of Londonderry, a large part of Wardsboro, the south part of Peru, northeast corner of Somerset, a little of the west of Windham, a little of south Landgrove, a very little of Dorest and of Weston.

Hoosick Map, 1897—Reprinted 1900

Nearly the whole of this map shows New York territory, but it includes a strip of Vermont two miles wide in Pownal, less north of this so that in Shaftsbury it is not more than a mile and a quarter wide. It shows thus a little of Pownal, Bennington and Shaftsbury.

Bennington Map, 1898

Except the small areas mentioned above, this map shows all of Bennington, all of Woodford, nearly all of Stamford, Pownal, and Glastenbury, a large area in Shaftsbury, and a very narrow strip of the west of Readsboro, Searsburg and Somerset.

Wilmington Map, 1899

On this map is found all of Wilmington, and all of Dover, nearly all of Whitingham, much of Somerset, Searsburg and Readsboro, also the west portion of Halifax, Marlboro and a little of Newfane, also a little of the south part of Wardsboro.

Brattleboro Map, 1893—Reprinted 1898

On this map is found the whole of Brattleboro, the whole of Dummerston, most of Guilford, all of Vernon, except the south border, the south part of Putney, east part of Marlboro, northeast part of Halifax, most of Newfane.

Keene Map, 1898

Only the southeast corner of Putney is in Vermont, the map being mostly in Massachusetts and New Hampshire.

Berlin Map, 1898—Reprinted 1900

As with some of the following maps, this would not be included in a list of Vermont maps, except that the plan adopted requires that every map, on which any, however small, part of the State is shown shall be included. This map is almost entirely given to areas in New York and Massachusetts. Only a little of southwest Pownal is shown.

Greylock Map, 1898—Reprinted 1913

This map shows more of Vermont than the preceding, but even so only a narrow strip of our southern border is found. The extreme southern border of Pownal, Stamford and a corner of Readsboro are shown. At the east end in Readsboro, the strip is not much more than a mile wide, and from this to the west end in Pownal it gradually narrows to a half mile.

Hawley Map, 1894—Reprinted 1898

The southern border of Readsboro, Whitingham and Halifax, a strip, rather more than a mile wide at the east end to half as wide on the west end, is all of Vermont shown on this map.

Greenfield Map, 1894—Reprinted 1898

This shows in Vermont the southern border of southeastern Halifax, Guilford and Vernon.

Warwick Map, 1894—Reprinted 1898

Only the southeastern corner of Vernon appears here as in Vermont.

Taconic Map, 1900

Two quadrangles in Vermont have been made on a scale of 125,000 feet to the inch. That is, in these the contour interval is 40 feet and linear distances are on a scale of two miles to an inch. Thus in a map of the same size as most of the Vermont topographical maps the area shown is in these four times as great. As all the details shown on the usual maps are the same as those shown on these special maps, ordinarily they are less useful to most persons, but for some purposes they are of special importance. The relation of those Vermont towns shown as found in the topographic features are of course more fully brought out. Six Vermont towns are shown on the Taconic map, *viz.:* Bennington, Shaftsbury, Glastenbury, Woodford, Pownal and Stamford.

Metawee Map, 1903—Reprinted 1913

Much more in Vermont is shown on this map than on the preceding, which is largely occupied by parts of New York and Massachusetts. The following Vermont town are shown, wholly or in large part, *viz.:* Arlington, Sunderland, Sandgate, Manchester Rupert, Dorset, Pawlet, Danby, Wells, Middletown and Tinmouth, while a smaller area is shown of Shaftsbury, Glastenbury, Poultney, and a little of Ira and Clarendon. The west half of the map is covered by New York towns.

Indian Stream Map, 1927

This map is nearly all of northern New Hampshire, but shows a little of northeastern Canaan in Vermont, including Beecher Falls. It is interesting as it shows the extreme upper reach of the Connecticut River from its outflow from Connecticut Lake. It is a War Department map and carries the series begun in the Rouses Point map, across the northern boundary of the United States well toward the Maine border.

Mascoma Map, 1928

Although this quadrangle is called a New Hampshire-Vermont map it contains very little of Vermont, only a small area in the northeastern part of Norwich. All the rest of this map is in New Hampshire. What is shown on the map is of very little importance to Vermonters, but a few elevations may be made out.

Hyde Park Map, 1928

This map includes the southeast part of Belvidere, the south part of Eden, most of the town, the northeast part of Waterville, nearly all of Johnson, nearly all of Morristown, almost the whole of Johnson, the whole of Hyde Park, a small area in northeastern Cambridge, the northeastern part of Stowe, the southwest part of Wolcott, the northwest part of Elmore.

Bellows Falls Map, 1928

More than half of this map is on the east side of the Connecticut River and therefore is in New Hampshire. It covers a considerable area of the east part of Rockingham, including the village of Bellows Falls, the south border of Springfield, the eastern half of Westminster, and the northeast part of Putney.

As has been stated, on some of the maps the whole of a given township is given, while in case of other townships only a part is covered by one map and the remainder of the town must be sought on another map, or in some cases on more than one. For convenience in ordering maps the following list is given by the aid of which anyone may easily find the sheet, or map which includes the area he wishes to examine.

LIST OF VERMONT TOWNS STATING ON WHICH SHEET, OR QUADRANGLE, EACH TOWN IS MAPPED

Name of Town	Name of Topographic Map	Part of Town Given on Map
Abnaki	Rouses Point	All.
Adamant	Montpelier	All.
Addison	Port Henry	All.
Albany	Irasburg	North part.
Alburg	Rouses Point	All.
Andover	Wallingford	A little, west part.
Arlington	Equinox	Nearly all.
Athens	Not surveyed	
Averill	Averill Lake	Nearly all.
Averys Gore Essex Co.	Island Pond	All.
Averys Gore Franklin Co.	Jay Peak	All.
Bakersfield	Enosburg Falls	A large part.
	Jay Peak	East part.
	Mansfield	Southeast corner.
Baltimore	Not surveyed	
Barnard	Randolph	North part.
	Woodstock	South part.
Barnet	Not surveyed	
Barre	Barre	Eastern part.
	Montpelier	Western part.
Barton	Memphremagog	North part.
Beecher Falls	Indian Stream	All.
Bellows Falls	Bellows Falls	All.
Belvidere	Jay Peak	North part.
	Hyde Park	South part.
Bennington	Bennington	Nearly all.
	Hoosick	West border.
Benson	Ticonderoga	North border.
	Castleton	A little, east border.
	Whitehall	Nearly all.
Berkshire	Enosburg Falls	Western part.
	Jap Peak	Eastern part.
Berlin	Montpelier	A little.
	Barre	Nearly all.
Bethel	Randolph	Nearly all.
Bloomfield	Averill	All.
Bolton	Camels Hump	All.
Bradford	Not surveyed	

Name of Town	Name of Topographic Map	Part of Town Given on Map
Braintree	Barre	North end, little.
	Rochester	North border.
	Randolph	A large part.
Brandon	Brandon	All.
Brattleboro	Brattleboro	All.
Bridgewater	Woodstock	All.
Bridport	Port Henry	A little, north part.
	Ticonderoga	Nearly all.
Brighton	Island Pond	Nearly all.
Bristol	Middlebury	All.
Brookfield	Barre	Northern part.
	Randolph	Southeast corner.
Brookline	Not surveyed	
Brownington	Memphremagog	All.
Brunswick	Averill	A small part.
Burke	Not surveyed	
Burlington	Burlington	All.
Cabot	Not surveyed	
Calais	Montpelier	Western part.
Cambridge	Mansfield	Nearly all.
	Hyde Park	Northeast corner.
Canaan	Averill	All.
Castleton	Castleton	All.
Cavendish	Not surveyed	
Charleston	Memphremagog	Nearly all.
	Island Pond	Eastern part.
Charlotte	Burlington	The greater part.
	Willsboro	A small part.
Chelsea	Strafford	Southeastern part.
	Barre	Northwest part.
Chester	Not surveyed	
Chittenden	Rutland	South part.
	Rochester	A large area.
Clarendon	Rutland	Nearly all.
	Brandon	A little, east part.
Colchester	Milton	Nearly all.
	Burlington	A little, north part.
Concord	Whitefield	A little southeast.
Corinth	Strafford	A little, south part.
Cornwall	Brandon	A large part.
	Ticonderoga	A little, west border.
Coventry	Memphremagog	West part.
	Irasburg	East part.
Craftsbury	Not surveyed	
Danby	Pawlet	A large part.
	Wallingford	A little.

Name of Town	Name of Topographic Map	Part of Town Given on Map
Danville	Not surveyed	
Derby	Memphremagog	All.
Dorset	Equinox	South part.
	Pawlet	Large area.
	Wallingford	Eastern border.
	Londonderry	A little.
Dover	Wilmington	The whole.
Dummerston	Brattleboro	The whole.
Duxbury	Camels Hump	Nearly all.
East Haven	Not surveyed	
East Montpelier	Montpelier	West part.
	Barre	A very little.
Eden	Jay Peak	North part.
	Hyde Park	Most of the town.
Elmore	Montpelier	Southwestern part.
	Hyde Park	Northwest part.
Enosburg	Enosburg Falls	About half on each map, west half.
	Jay Peak	Eastern half.
Essex	Milton	Nearly all.
	Burlington	South part.
	Mansfield	Little of northeast part.
Fairfax	Milton	Western part.
	St. Albans	Northwest part.
	Mansfield	East part.
Fairfield	Enosburg Falls	Nearly all.
	St. Albans	A little, west part.
Fairhaven	Whitehall	Western part.
	Castleton	Eastern part.
Fairlee	Strafford	Southeast part, little.
Fayston	Lincoln Mountain	A large part.
	Camels Hump	A little, north part.
Ferrisburg	Burlington	North border.
	Port Henry	West part.
	Middlebury	East part.
Fletcher	Enosburg Falls	A very little.
	Mansfield	Nearly all.
Fort Ethan Allen	Milton	All.
Franklin	Enosburg Falls	All.
Georgia	Milton	Southern part.
	St. Albans	North part.
Glastenbury	Equinox	North part.
	Bennington	A large part.
Glover	Not surveyed	
Goshen	Brandon	West part.
	Rochester	East part.
Grafton	Not surveyed	

Name of Town	Name of Topographic Map	Part of Town Given on Map
Granby	Not surveyed	
Grand Isle	Plattsburg	All.
Granville	Lincoln Mountain	A large part.
	Rochester	South part.
Greensboro	Not surveyed	
Groton	Not surveyed	
Guildhall	Not surveyed	
Guilford	Brattleboro	North part.
	Greenfield	South a little.
Halifax	Brattleboro	Northeast part, most.
	Wilmington	Northwest part.
	Greenfield	Southeast part.
	Hawley	Southern part.
Hanksville	Camels Hump	All.
Hancock	Rochester	All.
Hardwick	Not surveyed	
Hartford	Hanover	All.
Hartland	Hanover	A large part.
	Woodstock	Very little, southwest.
Highgate	St. Albans	Most.
	Enosburg Falls	Eastern part.
Hinesburg	Burlington	All.
Holland	Memphremagog	West part.
	Island Pond	East part.
Hubbardton	Castleton	All.
Huntington	Burlington	A small part.
	Camels Hump	Nearly all.
Hyde Park	Hyde Park	All.
Ira	Castleton	Most.
	Pawlet	A little.
Irasburg	Irasburg	A large part.
	Memphremagog	Eastern part.
Island Pond	Island Pond	All.
Isle La Motte	Rouses Point	All.
Jamaica	Londonderry	All.
Jay	Jay Peak	West part.
	Irasburg	Eastern part.
Jericho	Mansfield	North part.
	Burlington	Southwest part.
	Camels Hump	A large part.
Johnson	Hyde Park	All.
Kirby	Not surveyed	
Landgrove	Wallingford	North part.
	Londonderry	South part.
Leicester	Brandon	All.

Name of Town	Name of Topographic Map	Part of Town Given on Map
Lincoln	Lincoln Mountain	West part.
	Middlebury	East part.
Londonderry	Londonderry	Nearly all.
Lowell	Jay Peak	West half.
	Irasburg	East half.
Ludlow	Not surveyed	
Lunenburg	Whitefield	Large area, southeast.
Lyndon	Not surveyed	
Maidstone	Not surveyed	
Manchester	Equinox	All
Marlboro	Brattleboro	East part.
	Wilmington	West part.
Marshfield	Not surveyed	
Mendon	Rutland	All.
Middlebury	Middlebury	North part, includes the village.
	Brandon	South part.
Middlesex	Montpelier	All.
Middletown Springs	Castleton	North part.
	Pawlet	South part.
Milton	Milton	All.
Monkton	Burlington	North part.
	Middlebury	South part.
Montgomery	Jay Peak	All.
Montpelier	Montpelier	Nearly all.
Moretown	Montpelier	Northeast part.
	Barre	Southeast part.
	Lincoln Mountain	A little.
	Camels Hump	A little.
Morgan	Memphremagog	West part.
	Island Pond	Nearly all.
Morristown	Hyde Park	Nearly all.
	Mansfield	Small area.
Mount Holly	Wallingford	Nearly all.
Mount Tabor	Wallingford	All.
Newark	Not surveyed	
Newbury	Not surveyed	
Newfane	Brattleboro	Nearly all.
	Wilmington	A very little.
New Haven	Middlebury	All.
Newport	Memphremagog	East part.
	Irasburg	West part.
Northfield	Barre	Nearly all.
	Lincoln Mountain	Little of the west part.
North Hero	Rouses Point	All.

Name of Town	Name of Topographic Map	Part of Town Given on Map
Norton	Island Pond	Nearly all.
	Averill Lake	East part.
Norwich	Hanover	South part.
	Strafford	North part.
Orange	Not surveyed	
Orwell	Ticonderoga	Nearly all.
	Brandon	East part.
Panton	Port Henry	All.
Pawlet	Pawlet	All, practically.
Peacham	Not surveyed	
Peru	Wallingford	North part.
	Londonderry	South part
Pittsfield	Rutland	South part, little.
	Rochester	Nearly all.
Pittsford	Rutland	A little, southeast.
	Castleton	Nearly all.
	Brandon	Very little, northeast.
Plainfield	Not surveyed	
Plymouth	Woodstock	Large part.
	Rutland	A little west.
Pomfret	Hanover	East part.
	Woodstock	Large part.
Poultney	Castleton	Nearly all.
	Pawlet	South part.
Pownal	Bennington	Nearly all.
	Berlin	Little.
	Greylock	Little, south part.
Proctor	Castleton	All.
Putney	Brattleboro	South part.
	Bellows Falls	Northeast part.
Randolph	Randolph	Most.
Reading	Woodstock	North part.
	Not surveyed	South part.
Readsboro	Bennington	Little, west border.
	Greylock	Little, southern border.
	Hawley	Little, southern border.
	Wilmington	A large part.
Richford	Jay Peak	All.
Richmond	Burlington	West part, most.
	Camels Hump	East part.
Ripton	Brandon	West part.
	Middlebury	Southwest part.
	Rochester	East part.
	Lincoln Mountain	A little.
Rockingham	Bellows Falls	East part.
Roxbury	Lincoln Mountain	Southwestern part.
	Barre	Large part.

Name of Town	Name of Topographic Map	Part of Town Given on Map
Royalton	Strafford	Northeast corner.
	Randolph	Nearly all.
Rupert	Equinox	South part.
	Pawlet	North part.
	Cambridge	A very little.
Rutland	Rutland	Eastern part.
	Castleton	Western 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	Northeast part.
	Equinox	Southeast part.
	Cambridge	Northwest border.
	Hoosick	Southwest border.
Sharon	Hanover	Southeast border.
	Strafford	Nearly all.
Sheffield	Not surveyed	
Shelburne	Burlington	All.
Sheldon	St. Albans	West part.
	Enosburg Falls	Most.
Sherburne	Rutland	Nearly all.
	Woodstock	Eastern part.
Shoreham	Brandon	East part.
	Ticonderoga	Nearly all.
Shrewsbury	Rutland	A large part.
	Wallingford	South border.
Somerset	Londonderry	Northeast part.
	Wilmington	A large part.
South Burlington	Burlington	All.
South Hero	Plattsburg	All.
Springfield	Claremont	Nearly all.
	Bellows Falls	South border.
Stamford	Bennington	Nearly all.
	Greylock	A little.
Stannard	Not surveyed	
Starksboro	Burlington	Northwest part.
	Middlebury	A large part.
	Lincoln Mountain	Southeast part.
Stockbridge	Rutland	Southwest part, little.
	Woodstock	Southeast part.
	Rochester	Northwest.
	Randolph	Northeast, little.

Name of Town	Name of Topographic Map	Part of Town Given on Map
Stowe	Montpelier	A large part.
	Camels Hump	Southwest part.
	Mansfield	Northwest part.
Strafford	Strafford	All.
Stratton	Londonderry	Nearly all.
Sudbury	Brandon	All.
Sunderland	Equinox	All.
Sutton	Not surveyed	
Swanton	St. Albans	All.
Thetford	Strafford	West part.
Tinmouth	Pawlet	All.
Topsham	Not surveyed	
Townshend	Not surveyed	
Troy	Irasburg	All.
Tunbridge	Strafford	East part.
	Randolph	West part.
Underhill	Mansfield	North part.
	Camels Hump	South part.
Vergennes	Middlebury	Eastern part.
	Port Henry	Western part.
Vernon	Brattleboro	Nearly all.
	Greenfield	Very little.
	Warwick	Very little.
Vershire	Strafford	Nearly all.
Victory	Not surveyed	
Waitsfield	Lincoln Mountain	Nearly all.
	Barre	Very little.
Walden	Not surveyed	
Wallingford	Wallingford	Nearly all.
	Pawlet	A little.
Waltham	Middlebury	East part.
	Port Henry	West part.
Wardsboro	Londonderry	A large part.
	Wilmington	South part.
Warren	Lincoln Mountain	All.
Washington	Not surveyed	
Waterbury	Camels Hump	West part.
	Montpelier	East part.
Waterford	Not surveyed	
Waterville	Mansfield	Southwest part.
	Hyde Park	Northeast part.
Weathersfield	Claremont	Nearly all.
Websterville	Barre	All.
Wells	Pawlet	All.
West Fairlee	Strafford	All.

Westfield	Irasburg	East part.
	Jay Peak	West part.
Westford	Milton	West part.
	Mansfield	East part.
West Haven	Whitehall	All.
Westminster	Bellows Falls	East part.
Westmore	Memphremagog	Northwest part.
	Island Pond	Northeast part.
West Rutland	Castleton	All.
Weston	Londonderry	A little corner.
	Wallingford	Nearly all.
Westville	Not surveyed	
West Windsor	Woodstock	Little.
	Claremont	A large part.
	Hanover	Northeast part.
Weybridge	Middlebury	East part, most.
	Port Henry	West border.
Wheelock	Not surveyed	
Whiting	Brandon	All.
Whitingham	Wilmington	Nearly all.
	Hawley	South border.
Williston	Burlington	All.
Williamstown	Barre	Nearly all.
Wilmington	Wilmington	All.
Windham	Londonderry	West border.
Windsor	Hanover	North part.
	Claremont	A large part.
Winhall	Londonderry	All.
Winooski	Burlington	All.
	Hyde Park	West part.
Wolcott		
Woodbury	Not surveyed	
Woodford	Bennington	All.
Woodstock	Woodstock	Nearly all.
	Hanover	Northeast part.
Worcester	Montpelier	All.
Wrightsville	Montpelier	All.

REVISED LIST OF ALTITUDES IN VERMONT

Unless other authority is given, the elevation is that determined by the United States Geological Survey.

In those mountains which have more than one summit as in long ridges, the highest is that given.

All elevations given are above sea level. Lake Champlain is taken as 100 feet above sea level in recording heights near its border, so that in these elevations near the border of the Lake, 100

feet is added to the shore elevation, therefore a shore which rises 30 feet above the water of the Lake is 130 feet above sea level and is so recorded.

Partial lists of Vermont elevations have been given in earlier Reports. In some cases because of resurvey, or for other reason, the figures given in previous Reports are not those found in the following pages. Where discrepancy occurs the figures here given are those most accurate.

It is scarcely necessary to notice that the maps of the United States Topographical Survey are far more accurate than any which have hitherto been made.

In such a list as that which follows it is scarcely to be hoped that no errors have occurred and the author will be glad to be notified of any that may be discovered by those using the list.

In the elevations in many of the mountain towns much more complete lists could be given if all, or in some cases nearly all, the hills and mountains within the border of the town could be identified.

The difficulty, which the writer could not overcome, is that many very noticeable elevations have never been named. It will seem unbelievable to many, especially those living in a nearly level country, that in Vermont there are at the present time two hundred and ninety-seven peaks which are two thousand feet or more in height that have never been named, and consequently cannot be mentioned in a list like the following.

Not even local names can be found in these cases. The writer visited some of the most mountainous towns in his effort to get some name for summits the elevation of which had been determined by the Topographical Survey, but could not find anyone who could supply the lacking names. They are known only as "The Mountain" or "The Hill." In a few towns there are twenty-five or more rarely thirty, unnamed peaks any of which would be regarded as worthy of marked attention, were they located in a less rugged region. No count has been made of lesser peaks, those between one and two thousand feet altitude, but it is evident to anyone driving over the State that there are many.

In addition to what has been given on preceding pages, it may be said, that as many of the elevations in each town as it was possible to give, as determined by the United States Topographical Survey, are included in the following list. It will readily be understood that in giving the elevation of a village in a mountain region it is sometimes difficult to decide in what part of the village the figures should be taken, as different parts, it may be only a few rods from each other, are quite different in altitude. As far as possible when only one altitude is given, the "Bench Mark," if it is in the thickly occupied part of a village, is given, as in many cases it is placed in the heart of the village.

It may be helpful to explain that by "Bench Mark" is meant a permanent record left by the United States Engineers in some conspicuous locality. The bench mark is a mark cut into a cliff or large boulder, or, in the survey, of which we see these marks in Vermont, a copper bolt is placed in a mass of rock, a public building or some such place on which are given, besides the name of the Survey and such other lettering as may be desirable, figures stating the elevation as for example, the east side of the Post Office in Montpelier near the ground.

As will be noticed, many altitudes are given near school houses, as these are public buildings and the location usually well known and permanent or more so than a private dwelling.

A little duplication of what has appeared on foregoing pages will be found on those that follow in the lists given, but this cannot be avoided in all cases if the item is clearly stated. Also, in order that everything be fully understood, what in some instances may be considered as superfluous detail is given. The main object is to state the elevations that anyone consulting the maps may find readily what he is looking for. And some of the details will sooner or later be of great importance in the undertaking of some enterprise.

HOW TO OBTAIN THE MAPS

Of course the first thing is to have those maps which are needed for a given locality. The maps are on sale in Vermont by the following dealers and possibly by others at the price stated, 10 cents each. As a rule, the dealers here named keep only Vermont maps, but any map made anywhere in the United States can be obtained from the Director of the United States Geological Survey, Washington, D. C.

The List below is that furnished by the Department at Washington:

E. T. Griswold, Bennington.
Clapp and Jones, Brattleboro.
McAuliffe Paper Company, Burlington.
M. M. Miller, Newport.
National Survey Company, Chester.
Tuttle Company, Rutland.
Standard Stationery Store, Woodstock.

As stated, the price of single maps is ten cents, but if fifty or more are ordered, the price is $3 for the lot. These fifty may be alike or all different, or any desired assortment. But these lots

must be ordered from Washington. The List of Towns, given above enables one to find what maps he must have, if he wishes to know of the topography of a given locality. If one wants only the elevations in a single town, he will probably find them included in the last list here given, and it may not be necessary to get a map.

The enquirer must remember that all elevations are referred to sea level. Nearly all the measurements here given are those of the United States Topographical Survey, but in a few localities these were not available and instead the best authority that could be used is taken.

The following abbreviations are used in the list of towns:

Aneroid.	Aneroid Barometer.
B. A. R.	B. A. Robinson, Engineer.
B. M.	Bench Mark.
B. M. R. R.	Boston and Maine Railroad.
C. N. R.	Canadian National Railways.
C. P. R. R.	Canadian Pacific Railroad.
C. V. R. R.	Central Vermont Railroad.
M. C. R. R.	Maine Central Railroad.
M. W. R. R.	Montpelier and Wells River Railroad.
Rut. R. R.	Rutland Railroad.
St. J. &. L. C. R. R.	St. Johnsbury and L. C. Railroad.
U. Vt. E.	Engineers, University of Vermont.
N. S.	Not yet surveyed.

Unless indicated as above, all elevations are those determined by the United States Topographical Survey. Again let me urge careful study of such maps as are used in any locality. I also repeat that all previous lists are supplanted by the following:

LIST OF ALTITUDES IN VERMONT

MOUNTAINS, TOWNS, LAKES, VALLEYS, ETC.

Measurements mainly by the U. S. Topographical Survey

Locality	Authority	Altitude
Abnaki, North Hero		20
Ackworth, Bristol		630
Adamant, Calais		1,060
Adamant Pond, Calais		1,030
Adams Mountain		3,236
Addison, Village		280
Addison, Chimney Point		120
Addison, Snake Mountain		1,271
Addison, Town Line, north		200
Addison, West Addison		200

Locality	Authority	Altitude
Ajers Hill, Berkshire		1,336
Albany, Village	N. S.	.....
Albany, Brown School		900
Albany, Chamberlain Hill		1,500
Albany, Griggs Pond		846
Albany, Griggs School		940
Albany, Potters Pond		840
Albany, Vance School		1,435
Albany, White School		1,435
Albany, south part of township not yet surveyed.		
Alburg, Village	B. M.	123.6
Alburg, East Alburg	B. M.	116
Alburg, Bluff Point		140
Alburg, Center		140
Alburg, Coon Point		140
Alburg, Greenwood School		130
Alburg, Alburg Springs		130
Alburg, Alburg Tongue		140
Alburg, Warner Point		120
Highest point on Alburg northwest from East Alburg		240
Amsden, Weathersfield		590
Andover, Village	N. S.	.....
Andover, Terrible Mountain (west peak)		2,500
Andover, Terrible Mountain (east peak)		2,844
The greater part of Andover is not yet surveyed.		
Arlington, Village		691
Arlington, East		740
Arlington, West		595
Arlington, Big Spruce Mountain		2,510
Arlington, Buck Hill		1,700
Arlington, Grass Mountain		2,800
Arlington, Red Mountain		2,960
Arlington, Spruce Peak		2,570
Arlington, The Ball		2,715
Armstrong, Fletcher		555
Ascutneyville, Village	B. M.	412
Ascutney Mountain		3,144
Athens	N. S.	.....
Averill, Village		1,744
Averill, Black Mountain		2,840
Averill, Conway Dam		1,860
Averill, Forest Lake		1,660
Averill, Green Mountain		2,700
Averill, Lake Averill		1,684
Averill, Little Averill Lake		1,684

Locality	Authority	Altitude
Averill, Sable Mountain		2,785
Averill Mountain, Norton		2,240
Averys Gore, Gore Mountain		3,335
Averys Gore, Middle Mountain		2,920
Averys Gore, Round Mountain		2,920
Averys Gore, Unknown Pond		2,340
Bakersfield, Village	B. M.	736
Bakersfield, Bears Den Hill		1,460
Bakersfield, Basswood School		860
Bakersfield, Branch School		581
Bakersfield, Brown Pond		649
Bakersfield, Butternut Ridge (north peak)		1,120
Bakersfield, Butternut Ridge (south peak)		1,320
Bakersfield, Cooks School		930
Bakersfield, Egypt School		631
Bakersfield, Giddings Hill		1,300
Bakersfield, Highgate Forest School		596
Bakersfield, High School		640
Bakersfield, Kings Hill Mountain		1,880
Bakersfield, Kings Hill Pond		1,110
Bakersfield, Kings Hill School		915
Bakersfield, North School		780
Bakersfield, Peaked Mountain		1,900
Bakersfield, Ross School		1,000
Bakersfield, School Number 2		620
Bakersfield, School Number 11		500
Bakersfield, School Number 17		720
Bakersfield, West School		554
Bakersfield, Woodmans Hill		500
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.	.....
Baltimore, Hawks Mountain		2,040
Barber Mountain, Middleton		1,541
Bare Hill, Middleton		217
Bare Hill, Stamford		2,740

Locality	Authority	Altitude
Barker Mountain, Middletown		1,395
Barnard, Village, Methodist Church	B. M.	1,334
Barnard, East Barnard		1,000
Barnard, Cowdrey School		1,720
Barnard, Delectable Mountain (south end)		2,660
Barnard, Delectable Mountain (north end)		2,053
Barnard, Gamble School		1,500
Barnard, Lakota Lake		1,885
Barnard, Line Pond		1,360
Barnard, Locust Creek School		860
Barnard, Morgan School		1,120
Barnard, Mount Hunger		2,440
Barnard, Mount Hunger School		1,540
Barnard, North Road School		1,500
Barnard, Silver Lake		1,305
Barnet, Town Hall	Aneroid	555
Barnet, R. R. Station	B. & M. R. R.	452
Barnum Hill, Shoreham		496
Barnumville, Manchester		740
Barre, Entrance of City Hall		609.4
Barre, Aviation Field		1,180
Barre, Beckley Hill		1,040
Barre, Beckley Hill School		1,025
Barre, Bolster Reservoir		750
Barre, Brookside School		760
Barre, Carleton School		1,195
Barre, Cobble Hill School		1,060
Barre, East Barre		1,128
Barre, East Hill		1,360
Barre, East Road School		1,100
Barre, Goldsburg Hill		1,000
Barre, Perrin Hill		1,080
Barre, Graniteville		1,137
Barre, Hospital		929
Barre, Millstone Hill		1,700
Barre, Pecks Pond		1,019
Barre, Quarries		1,500
Barre, South Barre		740
Barre, Upper Graniteville		1,500
Barre, Websterville		1,313
Barre, West Hill		1,237
Barre, Wilson Cemetery		1,120
Barton, Village	B. M.	951
Barton, Baird School		1,160
Barton, Barton Mountain		2,235

Locality	Authority	Altitude
Barton, Country Club		960
Barton, Devereux School		1,360
Barton, Fisk School		1,300
Barton, Orleans	B. M.	740
Barton, Reservoir		1,140
Barton, Riverside School		760
Barton, Stillwater Swamp		1,300
Bartonsville, Rockingham	Rut. R. R.	487
Basin Harbor, Ferrisburg, Store		120
Battell Lodge, Lincoln		3,420
Battell Mountain, Ripton		3,471
Baxter Mountain, Sharon		1,530
Bear Mountain, Wallingford		2,262
Beebe Plain, Derby		760
Beebe Pond, Hubbardton		622
Beebe Pond, Sunderland		2,280
Beldens, New Haven		330
Bellows Balls, Station		309
Bellows Falls, 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
Belvidere, Center	B. M.	923
Belvidere, Center School		523.9
Belvidere, Corners		1,127
Belvidere, Junction		699
Belvidere, Laraway Mountain		2,760
Belvidere, Locke School		700
Belvidere, Lost Pond		2,460
Bennington, Bald Mountain		2,865
Bennington, Bingham Hill		740
Bennington, Court House		682
Bennington, Main and Bradford Streets		752.4
Bennington, Deerfield River (850 feet south of bridge)		1,831
Bennington, Monument		893
Bennington, Mount Anthony		2,345
Bennington, National Bank		671
Bennington, North Bennington		500
Bennington, Paper Mill Village		540
Bennington, Pine Hills, 5 miles south		969
Benson, Village		420
Benson Landing		120
Benson, Doughty Pond		680
Benson, Howard Hill		661

Locality	Authority	Altitude
Benson, Howard Hill, Village		380
Benson, Little Pond		502
Benson, Oak Hill		900
Benson, Perch Pond		503
Benson, Root Pond		400
Benson, Shaw Mountain		664
Benson, Sunset Lake		503
Benson, Willcox Hill		688
Berkshire, Village		700
Berkshire, Ayers Hill		1,326
Berkshire, Beechnut Ridge		2,300
Berkshire, Burleson Pond		520
Berkshire, Corey School		916
Berkshire, East Berkshire	B. M.	360
Berkshire, Little Pinnacle		860
Berkshire, Rice Hill		880
Berkshire, West Berkshire	B. M.	545
Berlin, Village		1,016
Berlin, Cox Brook School		720
Berlin, East Road School		1,100
Berlin, Irish Hill		2,120
Berlin, Montpelier Junction		520
Berlin, Pond		972
Berlin, Riverton	B. M.	589
Bethel, Ansel Pond		780
Bethel, Bethel Gilead		960
Bethel, Blueberry Mountain		1,540
Bethel, Camp Brook		1,096
Bethel, Christian Hill		1,320
Bethel, Christian Hill School		1,021
Bethel, East Bethel		570
Bethel, Flynn School		760
Bethel, Granite Quarries		1,120
Bethel, Heep Pinnacle		1,680
Bethel, Lee Hill		2,080
Bethel, Lillieville		937
Bethel, Lost Creek School		588
Bethel, Lost Nation School		2,007
Bethel, Naught Hill		1,320
Bethel, Oak Hill		1,860
Bethel, Old Church		760
Bethel, Olympus		1,236
Bethel, Olympus Mountain		2,480
Bethel, Pauls Peak		3,000
Bethel, Quarry Hill		1,401

Locality	Authority	Altitude
Bethel, Shaw Hill		1,060
Bethel, Woodbury Hill		1,400
Biddle Knob, Pittsford		2,020
Big Peak, Montgomery		3,800
Binghamville, Fletcher		574
Bird Mountain, West Rutland		2,210
Black Mountain, Dummerston		1,269
Black Mountain, Granite Quarry, Dummerston		700
Blissville, Castleton		480
Blodgett Mountain, Stamford		2,500
Bloomfield, Village		912
Bloomfield, Church	B. M.	1,014
Bloomfield, Big Dam		1,200
Bloomfield, Buzzell Hill		1,780
Bloomfield, Center School		1,014
Bloomfield, Dam No. 2		1,210
Bloomfield, Little Potash Mountain		1,740
Bloomfield, Potash Mountain		2,030
Bloomfield, Ridge (north peak)		2,457
Bloomfield, School No. 3	B. M.	983
Bloomfield, Snow Hill		1,880
Bloomfield, Spencer Hill		1,420
Bloomfield, Stone Dam		1,052
Blue Ridge Mountain, Mendon		3,293
Boardman Hill, Clarendon		1,315
Bolton, Village		342
Bolton, Bolton Mountain		3,725
Bolton, Bone Mountain		2,900
Bolton, Dunsmoor Lodge		2,640
Bolton, Green Mountain		3,300
Bolton, Notch		1,250
Bolton, Preston Pond		1,160
Bolton, R. R. Bridge No. 76		342
Bolton, Stimson Mountain		1,900
Bolton, West Bolton		991
Bondville, Winhall		1,220
Bone Mountain, Bolton		2,900
Bordoville, Enosburg		740
Bowlsville, Mount Holly		1,300
Bradford Village, R. R. Station, top of rail		405
Braintree, R. R. Station		779
Braintree, Braintree Hill, north end		1,700
Braintree, Braintree Hill, south part		1,532
Braintree, Brattles School		943
Braintree, Burridge School		1,183

Locality	Authority	Altitude
Braintree, Clough School		1,165
Braintree, East Braintree		720
Braintree, Ferry Hill		1,900
Braintree, Flint School		1,547
Braintree, Oak Hill		1,940
Braintree, Peth		846
Braintree, Riford Brook School		1,060
Braintree, Riford Hill		1,800
Braintree, Round Pond		1,400
Braintree, South Branch School		726
Braintree, Thresher Hill		2,040
Braintree, Village		787
Brandon, R. R. Station		394
Brandon, Village	B. M.	416
Brandon Inn		420
Brandon, Bridge over Mill Creek		416
Brandon, Burwell Pond		500
Brandon, Forestdale		595
Brattleboro, R. R. Station		240
Brattleboro, Canal Street School		295
Brattleboro, Elm Street Bridge		245
Brattleboro, Elm and Prospect Streets		320
Brattleboro, Front of High School		295
Brattleboro, Ginseng Hill		1,556
Brattleboro, Post Office		260
Brattleboro, Reservoir		380
Brattleboro, Retreat		220
Brattleboro, Round Mountain		1,508
Brattleboro, West Brattleboro		460
Breadloaf Mountain		3,823
Bridgewater, Village		820
Bridgewater, Bald Mountain		2,380
Bridgewater, Briggs		940
Bridgewater, Center		1,060
Bridgewater, Bull Hill		2,400
Bridgewater, Chateaugay	B. M.	1,417
Bridgewater, Cobb Hill		1,960
Bridgewater, Corners	B. M.	855
Bridgewater, Freestone Hill		2,140
Bridgewater, Grandmadam Hill		1,960
Bridgewater, North Bridgewater		1,200
Bridgewater, Mendell School		1,700
Bridgewater, Montague Hill		2,500
Bridgewater, Morgan Peak		2,600
Bridgewater, North Bridgewater		2,400

Locality	Authority	Altitude
Bridgewater, Ohio Hill		2,380
Bridgewater, Pinnacle		2,540
Bridgewater, Ragged Hill		2,080
Bridgewater, Raymond Hill		2,080
Bridgewater, Riverside School		950
Bridgewater, Southgate Mountain, north		1,740
Bridgewater, Southgate Mountain, south		1,720
Bridgewater, West Bridgewater		1,056
Bridport, Village		321
Bridport, Fletcher		373
Bridport, Plumies Point		160
Bridport, West Bridport		140
Briggs, Bridgewater		900
Briggs Corners, Shaftsbury		1,820
Brighton, Village	B. M.	1,171
Brighton, Back Pond		1,170
Brighton, Beecher Pond		1,227
Brighton, Bemis, Pond School		1,180
Brighton, Bluff Mountain		2,380
Brighton, Dollif Mountain		1,860
Brighton, East Brighton	B. M.	1,171
Brighton, Hancock Pond		1,520
Brighton, Haystack Hill		1,820
Brighton, Head of Pond School		1,200
Brighton, Iron Bridge School		1,227
Brighton, Island Pond		1,172
Brighton, Island Pond Village	B. M.	1,190
Brighton, McConneley Pond		1,274
Brighton, Mud Pond		1,300
Brighton, Nickerson School		1,300
Brighton, Nulhegan Pond		1,155
Brighton, Rosebrook Hill		1,660
Brighton, Spectacle Pond		1,173
Brighton, Sukes Pond		1,521
Brighton, Toad Pond		1,800
Bristol, Village at Hotel		575
Bristol, Casket Factory		510
Bristol, Flats		376
Bristol, Gilmore Pond		2,020
Bristol, Bristol Pond		460
Bristol, Gilmore Pond		2,040
Bristol, Higgins Pond		1,600
Bristol, Hogback Mountain, south end		1,850
Bristol, North Pond		2,140
Bristol, South Mountain		2,307

Locality	Authority	Altitude
Bristol, R. R. Station		570
Brocklebank Hill, Tunbridge		2,120
Brockways	Rut. R. R.	462
Bromley Mountain, Peru		3,260
Brookfield, Village		1,481
Brookfield, Bear Hill School		1,572
Brookfield, Brookfield Center		1,448
Brookfield, East Brookfield		714
Brookfield, Gilead School		1,020
Brookfield, Keyes School		1,367
Brookfield, Lamson Pond		1,600
Brookfield, Lamson School		1,617
Brookfield, North Branch School		718
Brookfield, No. 2 School		1,440
Brookfield, Pickles Pond		1,480
Brookfield, Southeast Hill School		1,140
Brookfield, South Pond		1,433
Brookfield, South Branch School		680
Brookfield, Sunset Lake		1,272
Brookfield, Twin Ponds		1,208
Brookfield, Warren Pond		1,282
Brookfield, West Brookfield		1,036
Brookfield, West Street School		1,422
Brookfield, South end of Williamstown Gulf		735
Brookline	N. S.	.....
Brookside, Westford		560
Brookside School, Westford		510
Brooksville, New Haven		240
Brownington, Village		1,249
Brownington, Center		1,014
Brownington, East Brownington School		1,383
Brownington, Evansville		1,116
Brownington, North Brownington School		1,195
Brownington, No. 7 School		1,257
Brownington, Brownington Pond		991
Brownington, Powers School		1,260
Brownington, Prospect Hill		1,360
Browns Ledges, Lowell		1,680
Browns Mountain, Starksboro		2,509
Brownsville, West Windsor		679
Bryant Mountain, Salisbury		1,122
Bryant Mountain, Wallingford		1,120
Buck Station, St. J. & L. C. R. R.		504
Buck Hollow, Fairfax		500
Buck Mountain, Waltham		927

Locality	Authority	Altitude
Bucketville, Wardsboro		1,100
Bucks Cobble, Salisbury		1,400
Burke, Village	N. S.	.....
Burke Mountain	Beers Atlas	3,500
Burlington, City Hall	B. M.	208
Burlington, Converse Dormitory, U. V. M.		373
Burlington, Green Mount Cemetery		313
Burlington, Lake View Cemetery, entrance		228
Burlington, Main and Champlain Streets		151
Burlington, Main and St. Paul Streets		190
Burlington, Main and South Union Streets		226
Burlington, Main and South Prospect Streets		364
Burlington, Rock Point (height above mean low water)		70
Burlington, Union Station		120
Burlington, Weather Bureau		381
Burlington, Williams Science Building		369
Burnhampton, Monkton		470
Burnt Mountain, Montgomery		2,626
Burnt Mountain, Fayston		3,168
Butlers Corners, Essex		519
Cabot, Village	N. S.	.....
Cadys Falls, Morristown	N. S.	.....
Calais, Village	N. S.	.....
Calais, Bliss Cemetery	Aneroid	1,036
Calais, Bliss Pond		1,209
Calais, Curtis Pond		1,214
Calais, Hawkins Pond		1,380
Calais, Hershey Hill		2,000
Calais, Kents Corners	Aneroid	1,210
Calais, Long Meadow Hill, north peak		2,020
Calais, No. 7 School		1,312
Calais, Robinson Hill		1,760
Calais, West Hill Church	Aneroid	1,335
Calais, Wheeler School		1,080
The eastern part of Calais is not yet surveyed.		
Cambridge, Village	B. M.	450
Cambridge, Station		454
Cambridge, Bartlett Hill		1,400
Cambridge, Bear Pond		3,500
Cambridge, Big Spring, Smugglers Notch	B. M.	1,803
Cambridge, Buker Hill		1,600
Cambridge, East Cambridge, Cemetery		480
Cambridge, Jeffersonville		480
Cambridge, Cambridge Junction		480
Cambridge, Lake of the Clouds, Mansfield		3,800

Locality	Authority	Altitude
Cambridge, Morses Mill		1,111
Cambridge, North Cambridge		565
Cambridge, Pleasant Valley		641
Cambridge, Seeley Hill		760
Cambridge, Smilley School		484
Cambridge, South Cambridge		874
Cambridge Warner Hill		1,200
Camels Hump Mountain, Duxbury		4,083
Canaan, Village	B. M.	1,042
Canaan, Beechers Falls	B. M.	1,105
Canaan, Canaan Hill		1,820
Canaan, Cold Hill		1,700
Canaan, Harriman Hill		2,040
Canaan, Islam Siding		1,020
Canaan, Line House		1,100
Canaan, Kemp Hill		1,780
Canaan, South Canaan School	B. M.	1,020
Canaan, State Fish Pond		1,347
Canaan, Wallis Pond		1,300
Canaan, Wallis Pond School		1,300
Cape Lookout Mountain, Goshen		3,298
Carmel Mountain, Chittenden		3,341
Caspian Lake, Greensboro	U. Vt. E.	1,404
Castleton, Village		450
Castleton, Barker Hill		1,210
Castleton, Bomoseen		450
Castleton, Blissville		460
Castleton, Bull Hill		920
Castleton, Castleton Corners		460
Castleton, Glen Lake		480
Castleton, Graham Hill		1,068
Castleton, Hooker Hill		880
Castleton, Hydeville		406
Castleton, Parker Hill		575
Castleton, Pond Hill		1,150
Castleton, Ransomevale		680
Castleton, Wallace Ledge		960
Castleton, West Castleton		480
Cavendish, Station	N. S. Rut. R. R.	929
Cedar Beach, Charlotte, south end		160
Center, Rutland		540
Centervale, St. Johnsbury	Aneroid	610
Centerville, Hartford		394
Centerville, Hyde Park		.....
Central Mountain, Marlboro		2,006

Locality	Authority	Altitude
Chaffee Mountain, Chittenden		2,506
Champlain, mean water level		96
Champlain, high water	White	103
Champlain, low water (October)	White	92.2
Charleston, Village, Center School		1,196
Charleston, Blake School		1,240
Charleston, Brick School		1,100
Charleston, Cole Hill School		1,170
Charleston, Crawford Hill		1,545
Charleston, East Charleston		1,200
Charleston, Echo Pond		1,248
Charleston, Echo School		1,300
Charleston, Deer Hill		1,400
Charleston, Goodwin Mountain		2,614
Charleston, Guy Hill School		1,400
Charleston, Hawkins School		1,240
Charleston, Little Hedgehog Hill		1,900
Charleston, Mud Pond		1,420
Charleston, Olive Hill		1,640
Charleston, Pensioner Pond		1,140
Charleston, Pierce Hill		1,940
Charleston, Plunkett School		1,120
Charleston, Stillwater Pond		1,368
Charleston, Toad Pond		1,146
Charleston, Trip Hill		1,720
Charleston, West Charleston	B. M.	1,028
Charlotte, Center		365
Charlotte, Alexander Corners		361
Charlotte, Barber Hill		420
Charlotte, East Charlotte		375
Charlotte, Jones Hill		600
Charlotte, Mount Philo		968
Charlotte, Mutton Hill		428
Charlotte, Pease Mountain		740
Charlotte, Pringle Corners		438
Charlotte, Fork of Road, west of Pease Mountain		253
Charlotte, Scott Pond		280
Charlotte, Station		180
Charlotte, Thompson Point		140
Chateaugay, Bridgewater	B. M.	1,417
Checkerberry, Milton		780
Chelsea, Village		820
Chelsea, Annis Hill		2,020
Chelsea, Bixby Hill		1,760
Chelsea, Holt Hill		1,775

Locality	Authority	Altitude
Chelsea, Merrill Hill		1,764
Chelsea, West Hill		1,448
Chester, Butternut Hill		1,870
Chester, Depot		599
Chester Depot	Rut. R. R.	599
Chester, Fullerton Inn	B. M.	623
Childs Mountain, Granville		2,800
Chimney Point, Addison		120
Chippenhook, Clarendon		860
Chiselville, Sunderland		800
Chittenden, Village		1,160
Chittenden, Bloodroot Mountain		3,520
Chittenden, Blue Ridge Mountain, north peak		3,060
Chittenden, Carmel Mountain		3,341
Chittenden, Corporation Mountain		3,100
Chittenden, Lookoff Mountain		2,600
Chittenden, Nickwaket Mountain		2,720
Chittenden, North Chittenden		1,040
Chittenden, Noyes Pond		2,280
Chittenden, Round Mountain		3,315
Chittenden, Steam Mill School		1,394
Chittenden, Thousand Acre Hill		2,400
Christian Hill, Bethel		1,320
Clarendon, Village	N. S.	.....
Clarendon, Chippenhook		840
Clarendon, Clarendon Springs		560
Clarendon, Boardman Hill		1,315
Clarendon, Bear Mountain, north peak		1,840
Clarendon, Cold River		560
Clarendon, East Clarendon		740
Clarendon, Flat Rock		1,375
Clarendon, North Clarendon		580
Clark, Sutton	N. S.	.....
Clark, Mountain, Tinmouth		1,961
Clark Mountain, Underhill		3,160
Cloverdale, Underhill		641
Coates Island, Malletts Bay		160
Cobble Hill, Bridgewater		1,960
Cobb Hill, Ripton		2,300
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

Locality	Authority	Altitude
Cobble Hill, Weston		907
Coburn Hill, Irasburg		.....
Colbyville, Waterbury		.....
Colchester, Village,		274
Colchester, Coates Island		160
Colchester, Colchester Pond		366
Colchester, R. R. Station	B. M.	328
Colchester, Fort Ethan Allen	B. M.	309
Colchester, Limekiln		320
Colchester, Malletts Head		280
Colchester, Munson Flat		116
Colchester, School No. 1		190
Colchester, School No. 2		410
Colchester, School No. 3		193
Colchester, School No. 4		132
Colchester, School No. 9	B. M.	224
Colchester, Town Farm		260
Colchester, Winooski, Main Street		200
Cold River, Clarendon		260
Cold River, Shrewsbury		850
College Hill, Jamaica		2,051
Colton Hill, Vershire		2,412
Comptois Hill, Shrewsbury		2,020
Concord, Village	N. S.	.....
Conicut, Newbury	N. S.	.....
Cooks Hill, Greensboro	U. Vt. E.	1,750
Cooper Hill, Dover		2,606
Copperas Hill, Shrewsbury		1,861
Copperas Hill, Strafford		1,160
Copperfield, Vershire		960
Copper Flat, Strafford		860
Corinth	N. S.	.....
Cornwall, Main Village	B. M.	775
Cornwall, Bridge three miles south		349.5
Cornwall, Library		365
Cornwall, The Ledge		380
Cornwall, Town Hall		374
Cornwall, West Cornwall		320
Corporation Mountain, Chittenden		3,000
Coventry, Village	B. M.	718
Coventry, Brownington Pond		991
Coventry, Cleveland Hill		1,460
Coventry, Center School		820
Coventry, Day School		800
Coventry, North Neighborhood School		910

Locality	Authority	Altitude
Coventry, Sargent Pond		940
Coventry, South Bay		682
Coventry, Walker Pond		973
Coventry, R. R. Station	B. M.	723
Coventry, West Hill School		800
Coy Mountain, Wells		2,060
Crawford Hill, Charleston		1,545
Craftsbury	N. S.	.....
Crookite Hill, Monkton		640
Cudding Hill, Shoreham		500
Curtis Hill, Tunbridge		1,561
Cushman Hill, Georgia		1,087
Cushman Mountain, Rochester		2,791
Cuttingsville, Village, Shrewsbury		1,040
Cutts Peak, Warren		4,080
Dana Hill, Pomfret		1,380
Danby, Village		700
Danby, Danby Four Corners		1,440
Danby Hill		2,112
Danby, Dorset Peak		3,804
Danby, Dutch Hill		2,480
Danby, Harrington Hill		2,260
Danby, Lilly Hill		1,500
Danby, Mount Hoag		2,200
Danby, Danby Pond		1,400
Danby, Walnut Hill		1,546
Danby, Woodlawn Mountain		3,072
Danville, Post Office	Aneroid	1,420
Danville, R. R. Station	St. J. & 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, Center		1,011
Derby, Bates Hill		1,360
Derby, Bates School		1,220
Derby, Beebe Plain		780
Derby, Blake School		1,064
Derby, Breezy Hill		1,160
Derby, Cobble Pond		1,121
Derby, Clyde Pond		878
Derby, Derby Pond		981
Derby, Dowling Hills		1,345

Locality	Authority	Altitude
Derby, Hopkins Hill School		1,440
Derby, Indian Point		780
Derby, Kittredge School		749
Derby, Lake Park		700
Derby Line, Custom House		1,028
Derby Line, Four Corners		1,243
Derby Line, Reservoir		1,260
Derby Line, Village	B. M.	1,029
Derby, Nelson Hill School		1,600
Derby, North Derby		720
Derby, North Derby		714
Derby, Salem Hill		1,540
Derby, Salem Pond		912
Derby, Salem Pond School		1,024
Derby, Shattuck Hill		1,220
Derby, Sugar Hill		1,540
Derby, Willey Granite Quarry		1,150
Deweys Mills, Hartford		1,080
Diamond Hill, Milton		540
Doctor Hill, Enosburg		.....
Dome, Pownal		2,754
Dorset, Village		940
Dorset, Dorset Mountain (Jackson Peak)		3,436
Dorset, Dorset Hill		2,880
Dorset, Dorset Pond (Emerald Lake)		740
Dorset, East Dorset		788
Dorset, Freedlyville		760
Dorset, Green Peak		3,185
Dorset, Netop Mountain		3,020
Dorset, North Dorset		700
Dorset, Owls Head		2,535
Dorset, South Dorset		920
Dorset, The Scallop		2,380
Dorset Peak, Danby		3,804
Dotham, Hartford		840
Double Top Mountain, Warren, northeast peak		1,820
Doughty Pond, Benson		700
Dover, Village		2,000
Dover, Cooper Hill		2,606
Dover, East Dover		1,080
Dover, Haystack Pond		2,800
Dover, Rice Hill		2,960
Dover, West Dover		1,720
Dover, Whites Hill		2,702
Dows, Walden, R. R. Station	St. J. & L. C. R. R.	1,411

Locality	Authority	Altitude
Dow Hill, Hinesburg		1,231
Dow Pond, Middlebury		440
Dowling Hill, Derby		1,345
Downingsville, Lincoln		1,324
Dowsville, Duxbury		1,288
Drinkwater Hill, Roxbury		2,040
Dummerston, Village		740
Dummerston, Black Mountain		169
Dummerston, East Dummerston		400
Dummerston, Prospect Hill		1,174
Dummerston, Putney, R. R. Station		260
Dummerston, West Dummerston		400
Dummerston, Wickopee Hill		1,656
Dummerston, Williamsville, R. R. Station		500
Dumpling Hill, Worcester		1,900
Dunmore Lake, Salisbury		571
Dunsmore Lodge, Bolton		2,640
Dutch Hill, Danby		2,480
Duxbury, Village, R. R. Station		340
Duxbury, Camels Hump or The Couching Lion		4,083
Duxbury, Dowsville		1,288
Duxbury, Durkee School		1,125
Duxbury, Monroes		1,420
Duxbury, Montclair Glen Lodge		2,660
Duxbury, Mount Ethan Allen		3,688
Duxbury, Mount Ira Allen		3,506
Duxbury, Phillips School		768
Duxbury, Scrabble Hill, south peak		2,309
Duxbury, Scrabble Hill School		1,104
Duxbury, South Duxbury		781
Eagle Ledge, Vershire		1,859
Eagle Mountain, Milton		600
East Albany	N. S.	.....
East Alburg	B. M.	116
East Arlington		740
East Barnard		1,000
East Barnet	N. S.	.....
East Barre		1,128
East Berkshire		446
East Bethel		570
East Braintree		720
East Brighton		1,171
East Brookfield		741
East Burke	Aneroid	830
East Cambridge, Cemetery		480

Locality	Authority	Altitude
East Charleston		1,198
East Charlotte		375
East Clarendon		740
East Concord	St. J. & L. C. R. R.	876
East Corinth	N. S.	.....
East Craftsbury	N. S.	.....
East Dorset		788
East Dover		1,080
East Dummerston		400
East Enosburg		750
East Fairfield	B. M.	424
East Franklin		380
East Fletcher		425
East Granville	N. S.	.....
East Haven	N. S.	.....
East Hardwick	N. S.	.....
East Highgate		222
East Jamaica	N. S.	.....
East Middlebury		1,021
East Montpelier	B. M.	728
East Orange	N. S.	.....
East Poultney		520
East Putney		288
East Randolph		606
East Roxbury	N. S.	.....
East Rupert		840
East Ryegate	N. S.	.....
East St. Johnsbury		785
East Swanton		756
Eden Village	B. M.	1,111
Eden, Asbestos Mine, Belvidere Mountain		2,150
Eden, Bean Mountain		2,206
Eden, Beaver Meadows		1,260
Eden, Big Muddy Pond		1,400
Eden, Bowen Mountain		2,300
Eden, Cooper Hill School		953
Eden, Corners		1,141
Eden, Corners School		1,141
Eden, Corey Pond		1,200
Eden Mills		1,198
Eden, Lake Eden		1,239
Eden, Lampher Mountain		1,340
Eden, Long Pond		1,137
Eden, North Road School		1,430
Eden, Ober School		1,278

Locality	Authority	Altitude
Eden, Pleasant Valley School		900
Eden, Ritterbush School		1,060
Eden, Round Pond		1,206
Eden, Rush Pond		1,300
Eden, South Pond		1,195
Eden, The Knob		1,738
Eden, Westcome School		929
Edgerton Hill, Pawlet		1,220
Egg Mountain, Sandgate		2,510
Elbow, Woodford		2,567
Elkhurst, Station	C. P. R. R.	672.7
Ellen Mountain, Warren		4,135
Elligo Pond, Craftsbury	Aneroid	890
Elm Hill, Derby		1,400
Elmore, Village at Post Office		1,145
Elmore, Delno School		1,249
Elmore, Hardwood Flats		1,570
Elmore, Hardwood Pond		1,562
Elmore, Little Elmore Pond		1,225
Elmore, No. 6 School		1,120
Elmore Pond		1,139
Elmore, Russ Pond		1,320
Ely, Station, top of rail	C. P. R. R.	430
Emerson, Rochester, R. R. Bridge, south of Station		782
Emerson, Rochester, Station		793
English Mills, Woodstock		840
Enosburg, Village, Center		875
Enosburg, Adams Pond		700
Enosburg, Austin School		1,060
Enosburg, Bordoville		740
Enosburg, East Enosburg		780
Enosburg Falls	B. M.	422
Enosburg, Gilberts Tannery		565
Enosburg, North Enosburg		402
Enosburg, Sampsonville		416
Enosburg, Sandhill School		625
Enosburg, School No. 2		460
Enosburg, West Enosburg		440
Enosburg, West Hill School		1,100
Enosburg, Woodward School		800
Enosburg, Wrights School		975
Equinox Mountain, Manchester		3,816
Essex, Village, Center		492
Essex Junction, Station		358
Essex, Beecher School		560

Locality	Authority	Altitude
Essex, Brigham Hill		1,032
Essex, Brigham Hill School		645
Essex, Butlers Corners		519
Essex, Nichols School		620
Essex, Pages Corners		550
Essex, Saxon Hill		920
Essex, School No. 2		360
Essex, Warner School		520
Evarts, Hartland	B. M.	383
Evansville, Brownington	B. M.	1,116
Fairfax, Village		349
Fairfax, Buck Hollow		620
Fairfax Falls	B. M.	434
Fairfax, Huntsville	B. M.	471
Fairfax, Sanderson Corner		500
Fairfax, Sand Hill		880
Fairfax, School No. 9		806
Fairfax, School No. 8		624
Fairfax, School No. 11		460
Fairfax, School No. 13		700
Fairfax, School No. 14		700
Fairfax, School No. 19		440
Fairfax, Silver Lake		783
Fairfield Village		500
Fairfield, Buckley School		980
Fairfield, Callan School		520
Fairfield, Creek School		368
Fairfield, East Fairfield	B. M.	424
Fairfield, Gould School		577
Fairfield, Fairfield Pond		550
Fairfield, Fox Hill		780
Fairfield, Herrick School		750
Fairfield, Leach Hill		1,400
Fairfield, Lost Nation School		836
Fairfield, McCarty School		800
Fairfield, Pine Hill		1,400
Fairfield, Pond School		611
Fairfield, Pumpkin Village School		675
Fairfield, St. Rocks		350
Fairfield, School No. 6		757
Fairfield, School No. 8		852
Fairfield, School No. 9		806
Fairfield, School No. 22		392
Fairfield, Soule School		626
Fairfield, Swamp School		680

Locality	Authority	Altitude
Fairhaven, Village		400
Fairhaven, R. R. Station		360
Fairhaven, Carver Falls		280
Fairhaven, Inman Pond		660
Fairhaven, Glen Lake		480
Fairlee, Beanville		860
Fairlee, R. R. Station		435
Fairlee, West Fairlee		780
Fairmount, East Montpelier		766
Fan Hill, Wells		1,731
Farman Hill, Lowell		1,380
Farmingdale, Middlebury		383
Fays Corners, Richmond	B. M.	563
Fayston, Village		1,209
Fayston, Burnt Rock Mountain		3,168
Fayston, Dana Hill		1,660
Fayston, Huntington Gap	B. M.	2,217
Fayston, North Fayston	B. M.	1,055
Fayston, No. 1 School		1,280
Fayston, No. 2 School		1,101
Fayston, No. 3 School		1,642
Fayston, No. 6 School		1,208
Fayston, Stark Mountain		3,585
Faysville, Glastenbury		1,840
Fennville, Leicester	B. M.	583
Fern Lake, Leicester		571
Ferdinand, Village	N. S.	.....
Ferdinand, Wenlock	B. M.	1,157
Ferdinand, Miles Pond		1,180
Ferdinand, south part not surveyed.		
Ferrisburg, Village	B. M.	218
Ferrisburg, North Ferrisburg		168
Ferrisburg, Marsh Hill		340
Ferrisburg, Shellhouse Mountain		680
Ferrisburg, Station		140
Ferrisburg, Town Hall		217
Fisk, Isle La Motte		120
Fishers Switch	Rut. R. R.	317
Fletcher, Village		628
Fletcher, Armstrong Mountain		1,420
Fletcher, Bald Hill		1,000
Fletcher, Binghamville		574
Fletcher, Black Hill		960
Fletcher, Buck Hollow School		720
Fletcher, Buck Mountain		1,360

Locality	Authority	Altitude
Fletcher, Church Hill		1,180
Fletcher, Cobble Hill		1,400
Fletcher, East Fletcher	B. M.	425
Fletcher, Ellenwood Hill		1,060
Fletcher, Fletcher Mountain, north peak		2,120
Fletcher, Fletcher Mountain, south peak		1,560
Fletcher, Gilson Mountain		1,940
Fletcher, Halfmoon Pond		919
Fletcher, Hooper School		740
Fletcher, King Hill		2,120
Fletcher, Leach Hill		1,620
Fletcher, Metcalf Pond		729
Fletcher, Oak Hill		1,200
Fletcher, Parsons School		630
Fletcher, Pond School		940
Fletcher, River View School		548
Fletcher, Ryan Mountain		1,100
Fletcher, Shepardson School		1,000
Fletcher, West Fletcher		780
Fletcher, Wintergreen Mountain		1,500
Fletcher, Bridport		573
Fletcher Hill, Woodstock		1,840
Florence, Pittsford		400
Florona Mountain, Monkton		660
Forbes Hill, West Haven		540
Forestdale, Brandon		595
Fort Ethan Allen, Colchester		309
Fox Cobble, Pawlet		1,611
Fox Hill, Fairfield		780
Fox Hill, Milton		380
Fox Pond, Wallingford		580
Franklin, Village	B. M.	426
Franklin, Browns Corners		325
Franklin, Bridgman Hill		849
Franklin, East Franklin		420
Franklin, Gates Hill		321
Franklin, Franklin Hill	B. M.	452
Franklin, Hillers Camp	B. M.	443
Franklin, Hubbard School		300
Franklin, Lake Carmi		435
Franklin, Little Pond		680
Franklin, Millers Camp	B. M.	443
Franklin, Minister Hill		800
Franklin, Pomeroy School		560
Franklin, School No. 5		530

Locality	Authority	Altitude
Franklin, School No. 6		750
Franklin, School No. 7		665
Franklin, School No. 8		640
Franklin, Shingle Hill		720
Fuller Mountain, Monkton		920
Gallup Hill, Montpelier		1,258
Gallups Mills, Victory	N. S.	.....
Garfield, Hyde Park	N. S.	.....
Garland Camp, Pittsfield		1,381
Gaskill, Waterford	N. S.	.....
Gassetts	Rut. R. R.	715
Gaysville, Stockbridge		661
Georgia, Village Center		385
Georgia, Bradley Hill		340
Georgia, Cushman Hill		1,100
Georgia, East Georgia		351
Georgia, Everett School		160
Georgia, Georgia Plains	B. M.	259
Georgia, Lost Lake		540
Georgia, Oakland		460
Georgia, St. Albans Hill		900
Georgia, School No. 2		340
Georgia, School No. 7		400
Georgia, School No. 6		386
Georgia, School No. 8		220
Georgia, School No. 11		400
Georgia, Silver Lake		783
Georgia, West Georgia		300
Giddings Hill, Bakersfield		1,300
Gile Mountain, Norwich		1,917
Gilette Hill, Hartford		1,220
Gilespie Mountain, Granville	N. S.	.....
Gilman Hill, Vershire		2,065
Gilmore Pond, Bristol		2,040
Ginseng Hill, Brattleboro		1,556
Glastenbury Mountain, Glastenbury		3,764
Glebe Mountain, Londonderry		2,944
Glen Ellen, Fayston		3,400
Glen Lake, Castleton		480
Glenton, Glover	White	526
Glover, Village	N. S.	.....
Goodhue Ledge, Vershire		1,800
Goodwin Mountain, Westmore		2,935
Gorhamtown, Poultney		660
Goshen, Village	B. M.	1,136

Locality	Authority	Altitude
Goshen, Cape Lookout Mountain		3,298
Goshen, Brandon Gap, Summit	B. M.	2,184
Goshen, Goshen Mountain		3,266
Goshen, Four Corners		1,408
Goshen, Hogback Mountain		2,290
Goshen, Mount Horrid		3,140
Goshen, Romance Mountain		3,020
Goshen, Sugar Hill		2,091
Goshen, White Rocks Mountain		3,307
Gove Hill, Thetford		1,362
Government Hill, Sudbury		1,075
Governor Mountain, Guilford		1,823
Grafton, Village	N. S.	.....
Graham Hill, Castleton		1,068
Granby, Village	N. S.	.....
Grand Isle, Village		160
Grand Isle, Pearl		200
Grand Isle, Robinson Point		140
Grand Isle, Highest Ground, north part		280
Grangeville, Pittsford		500
Grandmadam Hill, Bridgewater		1,960
Granite Hill, Wallingford		2,007
Graniteville, Barre		1,520
Grant, Westminster		2,007
Granville, Village	B. M.	1,013
Granville, Adam Mountain		3,236
Granville, Childs Mountain		2,720
Granville, East Granville		850
Granville, Gillespie Mountain		2,928
Granville, Lost Mountain		2,680
Granville Lower		960
Granville, Moss Glen Falls		1,360
Granville, Mount Cleveland		3,180
Granville, North Hollow School		1,520
Granville, Old Sixty Hill		1,660
Granville, Texas Falls		1,200
Granville, Texas School		1,840
Granville, West Hill School		1,351
Grannyhand, Hill, Strafford		1,710
Grass Mountain, Arlington		2,800
Grass Pond, Plymouth		1,560
Green Hill, Wallingford		1,213
Green Mount, Mount Tabor		2,340
Green Mountain, Wallingford		2,509
Green Peak, Dorset	(E. O. U. S.)	3,185

Locality	Authority	Altitude
Green River, Church	B. M.	749
Greensboro, Caspian Lake House	U. Vt. E.	1,463
Greensboro, Caspian Lake, low water	U. Vt. E.	1,404
Greensboro, lower step, Town Hall	U. Vt. E.	1,420
Greensboro, R. R. Station	U. Vt. E.	1,248
Greens Corners, Swanton		405
Greens Corners, on R. R. Track two miles north		453
Green River, Guilford		740
Greenvale, Thetford	N. S.	.....
Griffith, Mount Tabor		1,640
Griggs Mountain, Norwich		1,800
Griggs Pond, Albany		860
Groton Pond	M. & W. R. R. R.	1,094
Grout, R. R. Station	B. & M. R. R.	251
Grout Pond, Stratton		2,225
Grove, Halifax		1,460
Guildhall, Village	M. C. R. R.	874
Guildhall Falls	Beers	833
Guilford, Village		400
Guilford Center		700
Guilford, East Mountain, middle peak		1,232
Guilford, East Mountain, north peak		1,046
Guilford, Governors Mountain		1,823
Guilford, Green River		740
Guilford, Hinesburg		960
Guilford, Pulpit Mountain		1,249
Hadley Mountain, Lowell		2,400
Hager Hill, Woodford		2,800
Hale Hollow, Plymouth		960
Hale Mountain, Shaftsbury		1,420
Halfmoon Pond, Hubbardton		586
Halifax, Village, Church		1,600
Halifax, Grove		1,460
Halifax, South Halifax		840
Halifax, West Halifax		1,160
Hammond Hill, Mount Holly		1,721
Hammondsville, Reading		1,376
Hancock, Village		912
Hancock, Branch School		1,040
Hancock, Burnt Hill		2,980
Hancock, Cobble Hill		1,100
Hancock Mountain		2,089
Hancock, Hat Crown		2,560
Hancock, Kirby Peak		3,120
Hancock, Middlebury Gap	B. M.	2,149

Locality	Authority	Altitude
Hancock, Monastery Gap		2,400
Hancock, Monastery Mountain		3,222
Hancock, Pine Gap		2,540
Hancock, Pleiad Lake		2,120
Hancock, Silent Cliff		2,460
Hancock, Texas Falls		1,200
Hancock, Thunder Head		1,260
Hancock, Worth Mountain		3,300
Hancock, Village, Cross Roads		912
Hancock, Montgomery		780
Hanksville, Huntington	B. M.	849
Hanksville, two miles south of school		1,144
Hanksville, Fayston-Huntington Pass		2,217
Hardwick, Village, R. R. Station	St. J. & L. C. R. R.	861
Hardwood Flats, Elmore		1,570
Hardwood Pond, Elmore		1,562
Harmony Hill, Woodford		2,375
Harrington Hill, Danby		2,318
Harrington Cobble, Shaftsbury		1,460
Hartford, Village		400
Hartford, Birch School	B. M.	941
Hartford, Centerville		394
Hartford, Centertown School		834
Hartford, Deweys Mills		480
Hartford, Dothan		840
Hartford, Gillette Hill		1,220
Hartford, Hurricane Hill		1,220
Hartford, Jericho		1,065
Hartford, Loveland Hill		1,220
Hartford, Neals Hill		1,300
Hartford, Quechee		600
Hartford, Savage Hill		1,260
Hartford, Sprague Hill		1,200
Hartford, West Hartford	B. M.	420
Hartford, White River Junction	B. M.	267
Hartford, Wilder	B. M.	430
Hartland, Village		582
Hartland, R. R. Station		441
Hartland, Four Corners	B. M.	637
Hartland, Kent Hill		1,700
Hartland, North Hartland	B. M.	383
Hawkins Pond, Calais		1,380
Haynes Hill, Middletown		1,260
Haystack Mountain, Pawlet		1,919
Haystack Mountain, Lowell		3,223

Locality	Authority	Altitude
Haystack Mountain, Westmore	N. S.	.....
Haystack Mountain, Wilmington		3,462
Haystack Pond, Wilmington		2,660
Hazen Notch, Lowell, north end		1,200
Healdville, R. R. Station, Mount Holly		1,432
Heartwellville, east of Post Office		1,784
Hectorville, Montgomery	N. S.	.....
Heartwellville, Readsboro, Iron Bridge		1,363
Hedgehog Hill, Mount Holly		2,295
Hedgehog Mountain, Westmore		2,225
Herrick Mountain, Ira		2,727
Hersey Hill, Calais		2,000
Hewetts Corners, Pomfret		1,140
Highgate, Village		180
Highgate, Carter Hill		400
Highgate, Center		308
Highgate, Cutler Pond		250
Highgate, East Highgate		222
Highgate, Forest School		596
Highgate, Highgate Falls		260
Highgate, Proper Pond		212
Highgate, Rice Hill, south		820
Highgate, Rock River School	B. M.	99
Highgate, South Gore School		301
Highgate, Springs		127
Highgo Hill, Pawlet		1,318
High Knob, Shaftsbury		1,329
High Pond, Hubbardton		800
High Pond, Sudbury		820
Hillsboro Mountain, Starksboro		2,500
Hinesburg, Village	B. M.	341
Hinesburg, Dow Hill		1,231
Hinesburg, Hinesburg Pond		684
Hinesburg, High Rock		443
Hinesburg, Lincoln Hill		1,580
Hinesburg, Mechanicsville		436
Hinesburg, Rhode Island Corners		767
Hinesburg, South Hinesburg	B. M.	434
Hinesburg, Texas Hill		1,580
Hinkum Pond, Sudbury		717
Hoag Mountain, Danby		2,240
Hobart Mountain, Worcester		1,960
Hogback Mountain, Bristol south end		1,850
Hogback Mountain, Goshen		2,290
Hogback Mountain, Marlboro		2,347

Locality	Authority	Altitude
Hogback Mountain, Monkton		1,620
Hogback Mountain, Stowe		3,420
Holden, Chittenden		1,000
Holland, Village		1,405
Holland, Bazinet School		1,600
Holland, Beaver Pond		1,535
Holland, Dennicks Mill School		1,331
Holland, Duck Pond		1,540
Holland, East School		1,720
Holland, Green School		1,150
Holland, Holland Pond		1,430
Holland, John Mountain		2,337
Holland, Line Pond		1,600
Holland, Mead Pond		1,680
Holland, Page Hill		1,820
Holland, Round Pond		1,535
Holland, South School		1,462
Holland, Tice		1,140
Holland, Turtle Pond		1,438
Holland, Valley School		1,497
Holland, West Holland School		1,140
Holland, Wilcox Hill		1,840
Holt Hill, Chelsea		1,775
Hooker Hill, Castleton		880
Hopkinson Hill, Derby		1,246
Horrid Mountain, Goshen		3,140
Horsey Hill, Montpelier		2,000
Horton Pond, Hubbardton		488
Hortonville, Hubbardton		480
Hortonville, Mount Holly		1,540
Hortonville, Orwell		360
Howard Hill, Benson		661
Hubbard Hill, Thetford		1,682
Hubbardton, Village		460
Hubbardton, Austin Pond		468
Hubbardton, Beebe Pond		622
Hubbardton, Black Pond		626
Hubbardton, Bomoseen, Lake north end		413
Hubbardton, Breese Pond		555
Hubbardton, East Hubbardton		960
Hubbardton, Half Moon Pond		585
Hubbardton, High Pond		800
Hubbardton, Horton Pond		488
Hubbardton, Hortonville		480
Hubbardton, Keeler Pond		555

Locality	Authority	Altitude
Hubbardton, Roach Pond		537
Hubbardton, Round Pond		537
Hubbardton, Zion Hill		1,229
Huckleberry Hill, Richmond		1,520
Huffs Crossing, Orwell		228
Huff Pond, Sudbury		772
Hunger Mountain, Barnard		2,440
Huntington, Village		623
Huntington, Baby Stark Mountain		2,820
Huntington, Bald Hill		3,000
Huntington, Center at covered bridge		675
Huntington, Gillette Pond		740
Huntington, Hanksville	B. M.	849
Huntington, Molly Stark Mountain		2,960
Hurricane Hill, Hartford		1,220
Hurrican Hill, Woodstock		1,160
Hutchins, Montgomery	B. M.	674
Hyde Manor, Sudbury		823
Hyde Park, Village		660
Hyde Park, Barnes School		760
Hyde Park, Big Pond		1,258
Hyde Park, Blake Cemetery		1,000
Hyde Park, Centerville		800
Hyde Park, Clear Pond (north)		1,180
Hyde Park, Clear Pond (south)		1,160
Hyde Park, Cleveland Corner School		960
Hyde Park, Collins Pond		1,000
Hyde Park, Davis Hill		1,700
Hyde Park, Garfield		1,100
Hyde Park, Great Pond		1,280
Hyde Park, Half Pond		1,800
Hyde Park, Hyde Park School		1,220
Hyde Park, Hyde Pond		980
Hyde Park, McKinstry Hill		1,854
Hyde Park, McKinstry School		1,160
Hyde Park, Mud Pond		1,168
Hyde Park, North Hyde Park	B. M.	851
Hyde Park, Perch Pond		1,100
Hyde Park, Toothacher Hill		1,380
Hyde Park, Umbrella Hill		1,685
Hyde Park, Wiswell School	B. M.	889
Hyde Park, Zack Woods Pond		1,179
Hydeville, Castleton		405
Independence Mountain, Shoreham		300
Indian Hill, Pawlet		1,007

Locality	Authority	Altitude
Inman Pond, Fairhaven		640
Inwood, Barnet	B. & M. R. R.	504
Ira, Village		840
Ira, Herrick Mountain		2,727
Ira Allen Mountain, Duxbury		3,506
Irasburg, Village	B. M.	947
Irasburg, Allen Hill		1,580
Irasburg, Brighton School	B. M.	900
Irasburg, Burton Hill School		1,408
Irasburg, Chamberlain Hill, north peak		940
Irasburg, Kidder Pond		1,170
Irasburg, Kidder School		950
Irasburg, Morrill Hill School		988
Irasburg, Mud Pond		1,200
Irasburg, Potters Pond		840
Irasburg, Revoir Hill		1,132
Irasburg, Round Hill		1,340
Irasburg, Stony Hill		1,000
Irasburg, Ware School		800
Irasburg, White School		1,100
Irish Hill, Berlin		1,340
Island Pond, Brighton	B. M.	1,191
Isle La Motte, Village		210
Isle La Motte, Fisk		120
Isle La Motte, Light House		120
Isle La Motte, Reynolds Point		160
Isle La Motte, Sandy Point, top		200
Isle La Motte, The Head		240
Jackson Corners, Williamstown		884
Jackson, Pond, Mount Holly		1,740
Jacksonville, Whitingham		1,400
Jamaica, Village		700
Jamaica, Adam Pond		860
Jamaica, Ball Mountain		1,745
Jamaica, College Hill		2,051
Jamaica, Mud Pond		1,180
Jamaica, Rawconville		1,080
Jamaica, Sage Hill		2,140
Jamaica, Shatterack Mountain		1,920
Jamaica, West Jamaica		1,540
Jay, Village		922
Jay, North Jay Peak		3,400
Jay, North Jay School		980
Jeffersonville, Village		480
Jericho, Village		625

Locality	Authority	Altitude
Jericho, Birch Hill		1,220
Jericho, Cap Hill		1,100
Jericho, Covered Bridge		500
Jericho, Huckleberry Hill		1,640
Jericho, Jericho Center	B. M.	765
Jericho, Laisdell Hill		1,080
Jericho, Nashville		760
Jericho, North School		700
Jericho, No. 5 School		720
Jericho, No. 6 School		700
Jericho, No. 13 School		1,000
Jericho, South Hill		1,740
Jericho, R. R. Station		560
Jericho, The Cobble		1,300
Jerusalem, Starksboro		1,498
Jilson Hill, Whitingham		2,251
Jockey Hill, Shrewsbury		2,671
Joes Pond, Cabot	Aneroid	1,544
Johnson, Village		500
Johnson, Belding Pond		1,195
Johnson, Butternut Mountain		2,140
Johnson, Caper Hill		2,040
Johnson, Christy School		926
Johnson, Davis Neighborhood School		1,196
Johnson, East Johnson		584
Johnson, Hillside School		800
Johnson, Ithiel Fall		300
Johnson, Johnsburg		500
Johnson, Prospect Rock		1,040
Johnson, Ober School		800
Johnson, Riverside School		500
Johnson, Talc Mine		1,000
Johnson, Waterman School		700
Johnson, West Settlement		1,200
Jonesville, Richmond	B. M.	326
Jones Hill, Charlotte		600
Jones Mountain, Rochester		269
Kansas, Sunderland		840
Kelley Stand, Sunderland		2,140
Kent Hill, Hartland		1,700
Kew Hill, Waitsfield		1,900
Kibling Hill, Strafford		1,424
Kidder Pond, Irasburg		1,170
Killington Mountain, Sherburne		4,241
Kirby Mountain, Ripton		3,300

Locality	Authority	Altitude
Laisdell Hill, Jericho		1,050
Lake Averill,[1] Greater Averill		1,684
Lake Averill, Little Averill, Averill		1,740
Lake Bomoseen, Castleton		413
Lake Carmi, Franklin		435
Lake Caspian, Greensboro	U. Vt. E.	1,040
Lake Champlain, Burlington, high water		103
Lake Champlain, Burlington, C. T. Dock, July		94.39
Lake Champlain, Burlington, very low water		92
Lake Eden, Eden		1,239
Lake, Echo	N. S.	.....
Lake, Fern, Leicester		571
Lake, Forest, Averill		1,655
Lake, Fairlee, Fairlee	N. S.	.....
Lake, Glen, West Castleton		571
Lake Hortonia, Sudbury		482
Lake, Lakota, Barnard		1,885
Lake Lamoille, Morrisville		540
Lake, Maidstone	N. S.	.....
Lake Mansfield, Stowe		1,140
Lake Memphremagog, Newport		682
Lake Morey, Fairlee	N. S.	.....
Lake Pleiad, Hancock		2,120
Lake St. Catherine, Poultney		477
Lake Seymour, Morgan		1,279
Lake, Silver, Barnard		1,305
Lake, Willoughby, Westmore		1,179
Lakeside, Groton	M. & W. R. R. R.	1,094
Lamson Pond, Brookfield		1,555
Landgrove, Village		1,300
Landgrove, North Landgrove		1,360
Lanesboro, R. R. Station	M. & W. R. R R.	1,347
Leeland Hill, Lowell		1,720
Leicester Junction, crossing north of station		353
Lemington, Village		1,011
Lemington, Blodgett School		1,000
Lemington, Columbia Bridge		1,006
Lemington, Goff Hill		2,120
Lemington, Monadnock Mountain		3,140
Lemington, Simms Hill		1,760
Lemington, Todd Hill		1,940
Lewis, Village	B. M.	1,711

[1] The list of lakes here given is not complete but includes all that are important. There are some "Lakes" that are not as large as some "Ponds," but only bodies of water that are called "Lakes" are included. Ponds are placed under the towns in which they are located.

Locality	Authority	Altitude
Lewis, Buzzell Dam		1,510
Lewis, Lewis Mountain		2,575
Lewis, Lewis Pond	B. M.	1,857
Lewis, Peanut Dam		1,244
Lewiston, Norwich		440
Liberty Hill, Pittsfield		1,620
Lighthouse Hill, Williamstown		1,857
Lilly Hill, Stockbridge		1,586
Lilly Hill, Danby		1,500
Lilly Hill, Vernon		380
Lincoln, Village	B. M.	971
Lincoln, Alder Hill School		1,412
Lincoln, Bald Hill		1,620
Lincoln, Battell Lodge		3,400
Lincoln, Cooley Glen Club		3,140
Lincoln, Dowingsville		1,324
Lincoln, Lincoln Gap		2,424
Lincoln, Mt. Abraham		4,052
Lincoln, Mount Grant		3,661
Lincoln, Mount Pleasant		2,040
Lincoln, Murray School		1,310
Lincoln, No. 2 School		1,098
Lincoln, Prospect Rock		1,980
Lincoln, South Lincoln		1,313
Lincoln, West Lincoln		890
Lincoln Hill, Wells		1,380
Lincoln Mountain, Warren		4,013
Line Pond, Barnard		1,360
Line Pond, Stockbridge		1,380
Little Ascutney, Windsor	N. S.	.....
Little Day Peak, Montgomery		3,202
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, Village		1,400
Londonderry, Lowell Lake		1,290
Londonderry, South Londonderry		1,020
Londonderry, Winhall Station		920
Longmeadow Hill, Montgomery		2,120
Long Pond, Eden		1,137

Locality	Authority	Altitude
Long Pond, Milton		297
Long Pond, Westmore		1,835
Lookoff Mountain, Chittenden		2,600
Loomis Hill, Waterbury		1,340
Lost Lake, Georgia		540
Lost Mountain, Granville		2,680
Lost Pond, Belvidere		2,480
Lowell, Village	B. M.	996
Lowell, Belvidere Mountain	B. M.	3,360
Lowell, Browns Ledges		1,680
Lowell, Farman Hill		1,380
Lowell, Hadley Mountain		2,400
Lowell, Haystack Mountain		3,223
Lowell, LeClair School		1,360
Lowell, Leland Hill		1,800
Lowell, Lowell Mountain, south peak		2,120
Lowell, McAllister Pond		1,300
Lowell, Richards School		1,215
Lowell, South School		1,080
Lowell, Tillotson Mill		1,340
Lowell, Tillotson Peak		3,040
Lowell Lake, Londonderry		1,290
Lower Cabot	B. M.	947
Lower Granville		940
Lower Rochester, Talcville		825
Lower Waterford	N. S.	.....
Lone Hill, Stowe		1,666
Ludlow, Village, Station	Rut. R. R.	1,664
Ludlow Mountain, Mount Holly		3,372
Lunenburg		960
Lunenburg, Baldwin Mountain		1,981
Lunenburg, Neal Pond		1,195
Lunenburg, South Lunenburg		860
Lyford Pond, Walden	N. S.	.....
Lyndon	N. S.	.....
Lyndonville, Station	B. & M. R. R.	727
McAllister Pond, Lowell		1,300
McIndoes Falls, Barnet	B. & M. R. R.	441
McIntyre, Sunderland		2,060
McMaster Hill, Strafford		1,960
Madonna Peak, Morristown		3,668
Maidstone, Village		875
Mallett Head, Colchester		280
Manchester, Village		880
Manchester, Beartown		1,400

Locality	Authority	Altitude
Manchester, Barnumville		740
Manchester, Center		940
Manchester Depot		660
Manchester, Equinox Mountain		3,816
Manchester, Deer Knob		1,500
Manchester, Equinox Pond		1,100
Manchester, Mother Myrick Mountain		3,290
Mansfield Mountain, Chin		4,393
Mansfield Mountain, Nose		4,075
Maple Hill, Shaftsbury		1,706
Maple Hill, Woodford		2,740
Maquam, Swanton		108
Markham Mountain, Andover		2,489
Markham Mountain, Weston		2,480
Marlboro, Village		1,750
Marlboro, Ames Hill		1,760
Marlboro, Central Mountain		2,006
Marlboro, Higley Hill		2,301
Marlboro, Hogback Mountain		2,234
Marlboro, North Pond		1,480
Marlboro, South Pond		1,640
Marlboro, West Marlboro		1,780
Marshfield	B. M.	851
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
Mechanicsville, Hinesburg		436
Mechanicsville, Mount Holly		1,820
Mecawee Pond, Reading		1,440
Meetinghouse Hill, Norwich		1,201
Meetinghouse Hill		1,660
Minister Hill, Franklin		800
Memphremagog, Lake		682
Mendon, Village		1,000
Mendon, Bald Mountain		2,087
Mendon, Blue Ridge Mountain		3,293
Mendon, East Mountain		2,390
Mendon, Little Killington		3,951
Mendon, Mendon Peak		3,837
Merrill Hill, Chelsea		1,764
Middlebury, Village, bridge		366

Locality	Authority	Altitude
Middlebury, Chipman Hill		800
Middlebury, Dow Pond		440
Middlebury, East Middlebury		420
Middlebury, Farmingdale		383
Middlebury, Marble Ledge		280
Middlebury, Mead Chapel		455
Middlebury, Pine Hill		1,440
Middlebury, Station		355
Middle Mountain, Pawlet		1,965
Middlesex, Village	B. M.	540
Middlesex, Bear Swamp		1,700
Middlesex, Bridge over the river		508
Middlesex. Burnt Mountain		2,800
Middlesex, Center		1,185
Middlesex, Chase Mountain		2,280
Middlesex, Culver School		978
Middlesex, Densmore Mountain		2,720
Middlesex, Dudley School		920
Middlesex, Four Corners School		1,123
Middlesex, Lewis School		1,050
Middlesex, North Branch School		620
Middlesex Notch		1,140
Middlesex, Putnamville		700
Middlesex, Shady Rill	B. M.	760
Middlesex, Station		560
Middlesex, White Rock Mountain		3,220
Middletown, Barber Mountain		1,541
Middletown, Barker Mountain		1,395
Middletown, Burnham Hollow		780
Middletown, Coy Mountain, north peak		1,920
Middletown, Haynes Hill		1,260
Middletown, Morgan Mountain		1,740
Middletown, Spoon Mountain		2,030
Middletown Springs		887
Miles Mountain, Concord		2,470
Miles Pond, Concord		1,016
Miller Pond, Strafford		1,320
Mill Village, Vershire		1,040
Milton, Village, at bridge	B. M.	320
Milton, Arrowhead Mountain		947
Milton, Checkerberry		280
Milton, Cobble Hill		820
Milton, Diamond Hill		540
Milton, Eagle Mountain		600
Milton, Fox Hill		380

Locality	Authority	Altitude
Milton, Georgia Mountain		1,500
Milton, Hardscrabble School		950
Milton, Long Pond		297
Milton, Miltonboro		200
Milton, Milton Pond	B. M.	834
Milton, Roods Pond		374
Milton, School No. 3		300
Milton, School No. 5		324
Milton, School No. 6		740
Milton, School No. 8		220
Milton, School No. 9		380
Milton, School No. 10		325
Milton, School No. 12		200
Milton, Station		356
Milton, Town Farm		240
Milton, West Milton	B. M.	114
Mitchell 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
Monadnock, Lemington	N. S.	.....
Monastery Mountain, Hancock		3,222
Monkton, Village		533
Monkton, Barnumtown		472
Monkton, Cronkhite Hill		440
Monkton, East Monkton		660
Monkton, Florona Mountain		660
Monkton, Fuller Mountain		920
Monkton, Hogback Mountain, north peak		860
Monkton, Hogback Mountain, south peak		1,200
Monkton, Monkton Pond		491
Monkton, Monkton Ridge		598
Montague Hill, Bridgewater		2,500
Montgomery, Village	B. M.	492
Montgomery, Big Peak		3,800
Montgomery, Burnt Mountain, north peak		2,626
Montgomery, Burnt Mountain, south peak		2,740
Montgomery, Montgomery Center	B. M.	533
Montgomery, East Hill School		960
Montgomery, Hazen Notch School		1,177
Montgomery, Hectorville		800
Montgomery, Hutchins		580

Locality	Authority	Altitude
Montgomery, Jay Peak		3,864
Montgomery, Little Jay Peak		3,202
Montgomery, South School	B. M.	719
Montgomery, Hill West	B. M.	1,035
Montgomery, West Hill School		1,100
Montpelier	B. M. on Post Office	546.5
Montpelier, Main Street	B. M.	523
Montpelier, Cutler Cemetery		1,020
Montpelier, Culver School		840
Montpelier, East Montpelier Center		1,145
Montpelier, Green Mt. Cemetery, State Street	B. M.	522
Montpelier, Moss School		1,260
Montpelier, No. 1 School		1,260
Montpelier, No. 7 School		1,312
Montpelier, No. 8 School		1,200
Montpelier, No. 10 School		1,160
Montpelier, North Branch Cemetery		633
Montpelier, Slayton Pond		1,240
Moores, Pond, Plymouth		1,320
Moosalamoo Mountain, Salisbury		2,659
Moosehorn Mountain, Wells		1,845
Moretown, Village		620
Moretown, Chalcoot Pass		2,900
Moretown, Common		1,082
Moretown, Chase Mountain		2,060
Moretown, Gap		1,575
Moretown, No. 5 School		568
Moretown, No. 9 School		1,240
Moretown, Morse Mountain		3,468
Moretown, Rock Hill School		460
Moretown, Talc Mine		480
Morgan, Village		1,384
Morgan, Bear Hill		2,100
Morgan, Beechnut Ridge		2,300
Morgan, Cargill Hill		1,700
Morgan, Cargill School		1,414
Morgan, Morgan Center	B. M.	1,186
Morgan, Elan Hill		2,100
Morgan, Morgan Gore School		1,277
Morgan, Mud Pond, north pond		1,485
Morgan, Mud Pond, south pond		1,205
Morgan, Round Top		2,080
Morgan, Seymour Lake		1,279
Morgan, Toad Pond		1,829
Morgan, Underpass Pond		1,319

Locality	Authority	Altitude
Morgan, Wilcox Hill		1,880
Morrill Mountain, Strafford		1,103
Morristown, Village		759
Morristown, Beaver Meadow		2,185
Morristown, Billings School		1,300
Morristown, Bull Moose Hill		1,900
Morristown, Cadys Falls		600
Morristown, Chilcoot Pass		2,060
Morristown, Cheney School		1,063
Morristown, Cole School		1,305
Morristown, Joes Pond		732
Morristown, Lake Lamoille		560
Morristown, Lamson School		1,100
Morristown, Madonna Peak		3,668
Morristown, Molly Pond		740
Morristown, Morses Mountain		3,468
Morristown, Morristown Village	B. M.	681
Morristown, Moulds Lodge		2,200
Morristown, Mountain View Cemetery		700
Morristown, Mud City School		1,140
Morristown, North La Porte School		700
Morristown, North Randolph School		700
Morristown, Number Six School		1,100
Morristown, Red Bridge		959
Morristown, Ross Hill		1,380
Morristown, South La Porte School		762
Morristown, South Randolph School		777
Morristown, Sterling Cemetery		1,609
Morristown, Tyndal School		1,000
Morristown, Whiteface Mountain		3,715
Morristown, White Rocks		2,500
Morrisville, Village		681
Moscow, Stowe		640
Moscow, near trolley station		672
Mount Clarke, Underhill		3,160
Mount Cleveland, Granville		3,180
Mount Ellen, Warren		4,135
Mount Ethan Allen, Duxbury		3,688
Mount Grant, Lincoln		3,661
Mount Holly, Village		1,540
Mount Holly, Bowlsville		1,300
Mount Holly, Hammond Hill		1,721
Mount Holly, Healdville		1,500
Mount Holly, Hedgehog Hill		2,295
Mount Holly, Hortonville		1,840

Locality	Authority	Altitude
Mount Holly, Jackson Pond		1,840
Mount Holly, Ludlow Mountain		3,372
Mount Holly, Mechanicsville		1,840
Mount Holly, Mount Holly		2,045
Mount Holly, Patch Pond		1,750
Mount Holly, Proctor Hill		2,264
Mount Holly, Roger Hill		1,640
Mount Holly, Summit		1,500
Mount Holly, Tarbelville		1,560
Mount Hunger, Barnard		2,440
Mount Ira Allen, Duxbury		3,606
Mount Mansfield, Stowe, Chin		4,393
Mount Mansfield, Stowe, Nose		4,060
Mount Monadnock, Lemington		3,140
Mount Morrill, Strafford		1,700
Mount Mother Myrick, Manchester		3,290
Mount Nevins, Brookfield		2,080
Mount Norris, Lowell		2,050
Mount Pleasant, Lincoln		1,800
Mount Prospect, Williamstown		2,040
Mount Roosevelt, Ripton		3,580
Mount Tabor, Village		700
Mount Tabor, Buffum Pond		2,620
Mount Tabor, Green Mountain, north peak		2,509
Mount Tabor, Green Mountain, south peak		2,300
Mount Tabor, Griffith		1,620
Mount Tabor	N. S.	.....
Mount Tom, Plymouth		2,160
Mount Wilson, Ripton		3,756
Mud Pond, Irasburg		1,200
Mud Pond, Leicester		585
Mud Pond, Charlestown		1,420
Mud Pond, Orwell		740
Mud Pond, Sharon		860
Mud Pond, Stamford		2,760
Mutton Hill, Charlotte		428
Nancy Hanks Peak, Warren		3,800
Nashville, Jericho		760
Neal Hill, Hartford		1,300
Neal Pond, Lunenburg		1,195
Nebraska Notch Road, Underhill		1,760
Netop Mountain, Dorset		3,220
Newark, Cahill School		1,740
Newark, Village	N. S.	.....
New Boston, Norwich		500

Locality	Authority	Altitude
Newbury, R. R. Station		418
Newfane, Village		560
Newfane, Newfane Hill		1,630
Newfane, South Newfane		640
Newfane, R. R. Station		418
Newfane, Williamsville		580
New Haven, Village	B. M.	454
New Haven, Beldens		330
New Haven, Brooksville		260
New Haven, New Haven Junction		282
New Haven, New Haven Mills		340
New Haven, Spring Grove Camp Grounds		320
Newport, Village, near the lake		723
Newport, Allen Hill		1,100
Newport, Bear Mountain		1,800
Newport, Black Hill		2,180
Newport, Brown School		1,020
Newport Center	B. M.	792
Newport, Burlington School		893
Newport, Coburn Hill		1,460
Newport, County Road School		661
Newport, Farrar School		900
Newport, Federal Building		723
Newport, Lane School		683
Newport, Lake Memphremagog		682
Newport, Lake Road School		740
Newport, South Newport		1,387
Newport, Smith Pond		974
Newport, Summit Siding		924
Newport, West Hill School		878
Newport, Wright School		1,387
Nickwacket Mountain, Chittenden		2,720
Nigger Pond, Westmore		1,825
North Bennington, Village		580
Northboro, Village, Thetford	N. S.	.....
North Bridgewater		1,200
North Calais	N. S.	.....
North Clarendon		740
North Chittenden		1,040
North Concord	St. J. & L. C. R. R.	1,091
North Derby		720
North Dorset		700
North Duxbury		378.5
Northeast Mountain, Wells		2,125
North Enosburg		402

Locality	Authority	Altitude
North Fayston	B. M.	1,055
North Ferrisburg		168
Northfield, Village, R. R. Station		760
Northfield, Bald Mountain		2,586
Northfield, Brooks School		1,400
Northfield, Cox Brook School		780
Northfield, Dillingham School		1,280
Northfield, Dry Pond		1,220
Northfield, Fairground		860
Northfield, Glidden School		1,240
Northfield, Harlow Bridge School		825
Northfield, Holton School		917
Northfield, Irish School		2,120
Northfield, Northfield Falls		680
Northfield, No. 10 School		1,367
Northfield, No. 19 School		1,260
Northfield, Paine Mountain		2,405
Northfield, Rabbitt Hollow School		960
Northfield, Shaw Mountain		1,800
Northfield, South Northfield		839
Northfield, Turkey Hill		1,900
Northfield, Turkey Hill School		1,260
Northfield, University Grounds	B. M.	856
Northfield, Vatters Pond		1,440
Northfield, Waitsfield Gap		2,143
North Hartland	B. M.	383
North Hero, Bow Arrow Point		140
North Hero, Hibbard Point		160
North Hero, Hotel		120
North Hero, Pelot Point		140
North Hero, Stephenson Point		120
North Hero, Village		120
North Hero, Village, highest part		180
North Hero, Village, Hotel		120
North Pawlet		602
North Hyde Park	Aneroid	770
North Jay, School		920
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

Locality	Authority	Altitude
North Sheldon, Station		386
North Sherburne		1,260
North Thetford, Station		395
North Thetford, south of iron bridge		399
North Troy, Hotel		610
North Troy, Station		603
North Tunbridge		640
North Underhill		700
North Williston, near station		305
North Windham	N. S.	.....
North Wolcott	N. S.	.....
Norton, Norton Mills	B. M.	1,252
Norton, Averill Lake		1,684
Norton, Averill Mountain		2,240
Norton, Brousseau Mountain		2,714
Norton, Carpenter Camp		1,600
Norton, Halfway Pond		1,700
Norton, Hedgehog Hill		1,800
Norton, Lake, Village		1,349
Norton, Norton Pond		1,335
Norton, Roby School	B. M.	1,640
Norton, The Hurricane		1,600
Norwich, Village	B. M.	536
Norwich, Blood Mountain		780
Norwich, Bradley Hill		1,220
Norwich, Bragg School		950
Norwich, Gile Mountain		1,917
Norwich, Griggs Mountain		1,800
Norwich, Lewiston		460
Norwich, Lily Pond		480
Norwich, Meetinghouse Hill		1,200
Norwich, Moseley Pond		1,269
Norwich, New Boston		900
Norwich, Podunk School		900
Norwich, Rowell Hill		1,200
Norwich, Sargent Hill		1,240
Norwich, Stone Hill		1,600
Norwich, Spruce Hill		1,680
Norwich, West Norwich		1,140
Notown, Stockbridge		1,300
Noyes Pond, Chittenden		2,280
Nulheban R. R. Station, 158 miles to Montreal		923
Nulhegan River Bridge	C. N. R.	1,121
Oakland Station, crossing, 80 feet north		461
Oak Hill, Benson		900

Locality	Authority	Altitude
Ohio Hill, Bridgewater		2,380
Old City, Strafford		1,260
Old Knob, Poultney		1,150
Old Slaty Hill, Granville		1,780
Olympus, Village, Bethel		1,236
Olympus Mountain, Bethel		2,480
Orange, Village	N. S.	.....
Orcut Hill, Pawlet		1,460
Orleans, Village		740
Orleans, Reservoir		750
Orwell, Village		385
Orwell, Chipman Point		280
Orwell, Choate Pond		840
Orwell, Huffs Crossing		228
Orwell, Mount Independence		300
Orwell, Mud Pond		660
Orwell, North Orwell		273
Orwell, Spruce Pond		680
Owls Head Mountain, Dorset, Owls Nest		2,535
Owls Head, Richmond		1,160
Owls Head, Waterbury		1,600
Paine Mountain, Northfield		2,405
Panton, Village		200
Panton, Potash Point		120
Paper Mill Village, Bennington		540
Parker Hill, Castleton		575
Passumpsic, Station	B. & M. R. R.	531
Patch Pond, Mt. Holly		1,750
Pattern, Pawlet		860
Patterson Mountain, Vershire		2,321
Pawlet, Village		700
Pawlet, Bald Hill		2,088
Pawlet, Blossoms Corners		421
Pawlet, Burr Hill		1,980
Pawlet, Cleveland Hill		1,360
Pawlet, Edgerton Hill		1,120
Pawlet, Fox Cobble Hill		1,611
Pawlet, Haystack Mountain		1,919
Pawlet, Highgo Hill		1,316
Pawlet, Indian Hill		1,007
Pawlet, Lincoln Hill		1,300
Pawlet, Middle Mountain		1,965
Pawlet, North Pawlet		602
Pawlet, Orcutt Hill		1,460
Pawlet, Rock Hill		1,500

Locality	Authority	Altitude
Pawlet, Sargent Hill		1,260
Pawlet, Simmonds Hill		1,240
Pawlet, Spruce Top		1,378
Pawlet, Tadmer Hill		1,660
Pawlet, The Cobble		1,613
Pawlet, The Pattern		1,860
Pawlet, Town Hill		1,320
Pawlet, West Pawlet		500
Peabody Mountain, Weston		2,787
Pearl, Grand Isle		200
Pease Mountain, Charlotte		740
Pecks Pond, Barre		1,019
Pensioner Pond, Charleston		1,140
Perch Pond, Benson		500
Perkinsville, Weathersfield	N. S.	.....
Perry Hill, Waterbury		1,160
Peru, Village		1,660
Peru, Mount Tabor		3,886
Peru, Styles Peak		3,404
Petersburg Junction	B. & M. R. R.	467
Peth, Braintree		846
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		405
Pine Hill, Addison		1,400
Pine Hill, Middlebury		1,440
Pine Hill, Proctor		1,445
Pinnacle, Bridgewater		2,540
Pinnacle, Shoreham		655
Pinnacle, Stowe		2,240
Pinnacle, Warren	N. S.	.....
Pinnacle, Wells		1,940
Pinney Hollow, Plymouth		1,080
Pisgah Mountain, Westmore	N. S.	.....
Pittsfield, Village		892
Pittsfield, Brown School		1,040
Pittsfield, Garland Camp		1,381
Pittsfield, Liberty Hill		1,580
Pittsfield, Little Wilcox Peak		2,729
Pittsfield, River School		700
Pittsfield, South School		920

Locality	Authority	Altitude
Pittsfield, White School		880
Pittsfield, Wilcox Peak		2,921
Pittsford, Village		560
Pittsford, Biddle Knob		2,020
Pittsford, Blueberry Hill		1,724
Pittsford, Burr Pond		1,180
Pittsford, Butler Pond		660
Pittsford, East Pittsford		1,000
Pittsford, Florence		400
Pittsford, Grangerville		540
Pittsford, Pittsford Mills		420
Pittsford, Sargent Pond		600
Pittsford, R. R. Station		370
Pittsford, Whipple Hollow		600
Plainfield	B. M.	762
Plymouth, Village		1,420
Plymouth, Black Pond		1,380
Plymouth, Blueberry Hill		2,110
Plymouth, Blueberry Ledge		1,660
Plymouth, Five Corners		1,340
Plymouth, Grass Pond		1,580
Plymouth, Hale Hollow		980
Plymouth, Moores Ponds		1,340
Plymouth, Mount Tom		2,040
Plymouth, Pinney Hollow		1,040
Plymouth, Plymouth Ponds		1,395
Plymouth, Reading Pond		1,780
Plymouth, Salt Ash Mountain		3,218
Plymouth, Slack Hill		2,120
Plymouth, Plymouth Union		1,217
Pomfret, Village		1,220
Pomfret, Birch School	N. S.	.....
Pomfret, Breakneck Hill		1,100
Pomfret, Bunker Hill		1,520
Pomfret, Dana Hill		1,480
Pomfret, Hewetts Corners		1,120
Pomfret, North Pomfret		880
Pomfret, Seaver Hill		1,960
Pomfret, South Pomfret	B. M.	736
Pomfret, Thistle Hill		2,000
Pomfret, Vail Ridges		1,440
Pompanoosuc, R. R. Station	B. & M. R. R.	392
Pompanoosuc, Village		400
Pond Hill, Castleton		1,150
Pond Mountain, Vernon		1,190

Locality	Authority	Altitude
Pond Mountain, Wells, north peak		1,518
Pond Mountain, Wells, south peak		360
Post Mills, Thetford		700
Potter Pond, Irasburg		840
Poultney, Village		431
Poultney, East Poultney		480
Poultney, Gorhamtown		640
Poultney, Lily Pond		477
Poultney, Moss Hollow		800
Poultney, Old Knob		1,150
Poultney, St. Catherine Lake		477
Poultney, St. Catherine Mountain		1,277
Poultney, South Poultney		690
Poultney, Spaulding Hill		1,620
Poultney, Spruce Knob		2,320
Poultney, Station		430
Poultney, Town Hall		1,100
Pownal, Village	B. M.	549
Pownal, Center	B. M.	986
Pownal, Carpenter Hill		1,640
Pownal, Mason Hill		1,660
Pownal, Methodist Church	B. M.	549
Pownal, School House	B. M.	629
Pownal, Station		550
Pownal, The Dome		2,754
Pownal, Wrights Mill	B. M.	539
Preston Pond, Bolton		1,160
Preston, Hill, Thetford		1,480
Prindle Corners, Charlotte		436
Pritchard Mountain, St. George		1,140
Proctor Lodge, Ripton		2,580
Proctor, Village		477
Proctor, Pine Hill		1,445
Proctor, Hotel		480
Proctor, Marble Mills	B. M.	377
Proctor Hill, Mt. Holly		2,264
Prospect Hill, Dummerston		1,174
Prospect Hill, Westford		1,046
Proctorsville, R. R. Station	Rut. R. R.	928
Prospect Mountain, Woodford		2,690
Pulpit Mountain, Guilford		1,249
Pumpkin Hill	St. J. & L. C. R. R.	986
Purchase Hill, Tinmouth		2,544
Putnamville, Middlesex		700
Putney, Village		580

Locality	Authority	Altitude
Putney, Bare Hill		1,140
Putney, East Putney	B. M.	488
Putney, R. R. Station		260
Putney, East Putney Station		300
Queen City Park, Burlington		150
Quechee, Hartford, R. R. Station		600
Quimby Mountain, Sharon		1,699
Ragged Hill, Bridgewater		2,080
Randolph, Village	B. M.	694
Randolph, Adams School		1,380
Randolph, Archer School		1,400
Randolph, Beanville School		720
Randolph, Blaisdell School		1,100
Randolph, Center		1,384
Randolph, East Randolph	B. M.	606
Randolph, Fish Hill School		840
Randolph, Hebard Hill, north part		1,500
Randolph, North Randolph	B. M.	671
Randolph, Old Stone School		685
Randolph, Osgood Hill		1,580
Randolph, Osgood Hill School		1,200
Randolph, Reservoir		950
Randolph, South Randolph	B. M.	563
Randolph, Temple School		940
Ransomvale, Castleton		680
Rattlesnake Point, Salisbury		1,800
Rawsonville, Jamaica		1,070
Raymond Hill, Bridgewater		2,080
Ray Pond, Wilmington		1,840
Reading, Village		1,067
Reading, Baileys Mills		1,780
Reading, Brown School		660
Reading, Long Hill, south part		2,600
Reading, Mecawee Pond		1,440
Reading, Reading Hill School		1,140
Reading, Reading Pond		1,780
Readsboro, Village		1,180
Readsboro, Falls		1,550
Readsboro, Heartwellville, Post Office		1,784
Red Mountain, Arlington		2,960
Red Rock, Hinesburg		1,560
Red Rocks, Burlington		160
Revoir Hill, Coventry		1,132
Rhode Island Corners, Hinesburg		767
Rice Hill, Dover		2,960

Locality	Authority	Altitude
Rice Hill, Highgate, north end		820
Rice Mills, Thetford		640
Rice Mountain, Roxbury		3,060
Richardson Hill, Strafford		1,715
Richford, Village, north part		504
Richford, Village, south part		477
Richford, East Richford		540
Richford, Guillemette Pond		760
Richford, Hardwood Hill		1,160
Richford, School No. 4		740
Richford, South Richford		800
Richford, Station	C. P. R. R.	504
Richford, Station	C. V. R. R.	564
Richford, Stevens Mills		520
Richford, Town Hall		476
Richmond, Village	B. M.	319
Richmond, Chamberlain Hill		920
Richmond, Fays Corners		563
Richmond, Gillette Pond		740
Richmond, Huckleberry Hill		1,520
Richmond, Jonesville	B. M.	336
Richmond, Owls Head		1,160
Richmond, Richmond Pond		629
Richmond, Tower School		562
Richmond, Town Hall		476
Richmond, Yantz Hill		1,060
Richville, Shoreham Center		340
Ricker Mountain, Waterbury		3,401
Ripton, Village	B. M.	1,017
Ripton, Battell Mountain		3,471
Ripton, Bread Loaf Inn		1,375
Ripton, Bridge over brook	B. M.	1,017
Ripton, Bread Loaf Mountain		3,823
Ripton, Cobb Hill		2,300
Ripton, Fisher School		1,415
Ripton, Mount Roosevelt		3,580
Ripton, Mount Wilson		3,756
Ripton, Proctor Lodge		2,580
Riverside, Jericho, bridge over West River		696
Riverton, Berlin Station	B. M.	600
Roach Pond, Hubbardton		537
Robinson Hill, Shrewsbury		2,779
Robinson, Rochester		1,004
Rochester, Village	B. M.	837
Rochester, Alexander Hill		1,840

Locality	Authority	Altitude
Rochester, Austin Hill		2,274
Rochester, Braintree Gap		2,000
Rochester, Braintree Mountain, south peak		374
Rochester, Branch School		914
Rochester, Brandon Gap	B. M.	2,184
Rochester, Corner School		1,085
Rochester, Deer Mountain		2,200
Rochester, Emerson		825
Rochester, Jerusalem School		1,600
Rochester, Jones Mountain		2,096
Rochester, Little Hollow School		1,480
Rochester, Little Pico Mountain		2,315
Rochester, Maple Hill School		1,420
Rochester, Mount Cushman		2,880
Rochester, North Hollow School		1,500
Rochester, Philadelphia Peak		3,168
Rochester, Randolph Gap		2,353
Rochester, River School		800
Rochester, Robinson		1,004
Rochester, Rochester Mountain		2,952
Rochester, Rogers Peak		2,200
Rochester, South Hollow School		1,720
Rochester, Talcville		825
Rochester, West Hill School		1,720
Rochester, Williams Talc Mine		1,980
Rock Hill, Pawlet		1,506
Rockingham, Village		480
Rockingham, Barber Park		460
Rockingham, Bellows Falls (see under B above)		350
Rockingham, Brockway Mills		457
Rockingham, Coburn Hill		980
Rockingham, Darby Hill		1,160
Rockingham, Hogan Hill, south peak		940
Rockingham, Oak Hill		840
Rockingham, Minards Pond		614
Rockingham, Parker Hill		1,220
Rockingham, Parker Hill School		950
Rockingham, Sand Hill		520
Rockingham, Saxtons River Village		500
Rockingham, Signal Hill		1,240
Rockville, Starksboro		535
Roger Hill, Mt. Holly		1,640
Roods Pond, Milton		374
Roods Pond, Williamstown		1,400
Round Hill, Irasburg		1,340

Locality	Authority	Altitude
Round Hill, Shrewsbury		1,680
Round Mountain, Brattleboro		1,508
Round Mountain, Chittenden		3,315
Roundtop Mountain, Underhill		3,371
Rowell Hill, Norwich		1,160
Roxbury, Village	B. M.	1,007
Roxbury, Belcher Hill		2,260
Roxbury, Bowman School		1,460
Roxbury, Bull Run School		1,058
Roxbury, Cram Hill School		1,734
Roxbury, Drinkwater Hill		2,040
Roxbury, East Roxbury		1,202
Roxbury, Fish Hatchery		960
Roxbury, Vt. Marble Company's Quarry		1,120
Roxbury, Rice Mountain		3,060
Roxbury, Roxbury Flat		1,000
Roxbury, Teelawocket Camp		1,080
Roxbury, Warren Road School		1,400
Royalton, Village		500
Royalton, Broad Brook Mountain, south peak		1,521
Royalton, Broad Brook School		800
Royalton, Elephant Hill		1,120
Royalton, Hickey School		1,139
Royalton, Howard School		1,340
Royalton, Kents Lodge		1,500
Royalton, North Royalton		520
Royalton, Royalton Hill, south peak		1,500
Royalton, Russ Hill		1,520
Royalton, Russ School		1,061
Royalton, School No. 6	B. M.	560
Royalton, School No. 9	B. M.	504
Royalton, Sewall School		729
Royalton, South Royalton	B. M.	502
Rupert, Village		814
Rupert, Antone Mountain		2,660
Rupert, Burnt Hill		2,500
Rupert, East Rupert		840
Rupert, Haystack Mountain		2,120
Rupert, Masters Mountain		2,410
Rupert, North Rupert		745
Rupert, Rupert Mountain		1,860
Rupert, Shatterack Mountain		2,376
Rupert, Station		800
Rupert, West Rupert		760
Russ Pond, Elmore		1,320

Locality	Authority	Altitude
Rutland, City at Station		560
Rutland, Center Rutland, Station		540
Rutland, Clark Hill		1,600
Rutland, East Street and Jackson Ave.		600
Rutland, Evergreen Cemetery		540
Rutland, Killington Ave. and Stratton Road		820
Rutland, Post Office		600
Rutland, South Main Street, R. R. Crossing		545
Rutland, West Rutland		500
Ryegate, Station	B. & 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, Aldis Hill		840
St. Albans, Bellevue Hill		1,410
St. Albans, French School		1,000
St. Albans, Hathaway Point		110
St. Albans, Lake and Main Streets		409
St. Albans, Point School		110
St. Albans, Albans Point		120
St. Albans, School No. 6		480
St. Albans, School No. 20		113
St. Albans, South and Congress Streets		600
St. Albans, Station	B. M.	400
St. Albans, Tuller School		180
St. Albans, Weeds Crossing		660
St. Albans Hill, Georgia		810
St. Catherine, Lake, Poultney		477
St. Catherine Mountain, Poultney		1,227
St. George, Village		500
St. George, Mount Pritchard		1,140
St. Johnsbury, Atheneum	Aneroid	600
St. Johnsbury, Center	Aneroid	610
St. Johnsbury, Court House	Aneroid	665
St. Johnsbury, Weather Bureau		711
Salem Hill, Derby		1,540
Salem Pond, Derby		963
Salisbury, Village		440
Salisbury, Bryant Mountain		1,122
Salisbury, Lake Dunmore		571
Salisbury, Mount Moosalamoo		2,659
Salisbury, Pine Hill		1,820
Salisbury, Station		357
Salisbury, Sunset Hill		925

Locality	Authority	Altitude
Salisbury, West Salisbury		420
Salt Ash Mountain, Plymouth		3,218
Samsonville, Enosburg		416
Sandgate, Village		820
Sandgate, Bear Mountain, south peak		3,320
Sandgate, Beartown		1,400
Sandgate, Egg Mountain		2,510
Sandgate, Minister Hill		2,117
Sandgate, Moffit Mountain		2,278
Sandgate, Swearing Hill		2,040
Sargent Hill, Norwich		1,240
Sargent, Hill, Pawlet		1,279
Sargent Pond, Coventry		940
Saxon Hill, Essex		920
Saxtons River Village		920
Scallop Mountain, Dorset		2,380
Scott Pond, Charlotte		280
Scrabble Hill, Duxbury, south peak		2,309
Scragg Mountain, Waitsfield		2,628
Searsburg, Village		1,760
Seaver Hill		960
Seymour Lake, Morgan		1,279
Shaftsburg, Village	B. M.	883
Shaftsbury, Briggs Corners		840
Shaftsbury, Bucks Cobble		1,400
Shaftsbury, Center		1,480
Shaftsbury, Hale Mountain		1,420
Shaftsbury, Harrington Cobble		1,460
Shaftsbury, Maple Hill		1,706
Shaftsbury, South Shaftsbury		740
Shaftsbury, Trumbull Mountain		1,600
Shaftsbury, West Mountain		2,022
Shaker Mountain, Starksboro		1,920
Sharon, Village		502
Sharon, Boyds Hill		1,480
Sharon, Baxter Hill		1,530
Sharon, Bush Pond		1,180
Sharon, Mitchell Pond		900
Sharon, Mud Pond		740
Sharon, Quimby Mountain		1,699
Sharon, Standing Pond		1,380
Sharon, Station		503
Shatterack Mountain, Jamaica		1,920
Shatterack Mountain, Rupert		2,376
Shattuck Hill, Derby		1,220

Locality	Authority	Altitude
Shaw Mountain, Benson		664
Shawville, Sheldon		380
Sheffield	N. S.	.....
Shelburne, Village	B. M.	174
Shelburne, Shelburne Falls		140
Shelburne, Station		160
Sheldon, Village	B. M.	374
Sheldon, Camp Ground		280
Sheldon, Duffy Hill School		960
Sheldon, East Sheldon		578
Sheldon, Sheldon Junction		340
Sheldon, North Sheldon		392
Sheldon, North Sheldon School		392
Sheldon, Rice Hill		440
Sheldon, School No. 1		420
Sheldon, Shawville		388
Sheldon, Sheldon Hill		920
Sheldon, South Franklin	B. M.	372
Sheldon, Sheldon Springs	B. M.	345
Sheldon, Webster School	N. S.	.....
Shellhouse Mountain, Ferrisburg		680
Sherburne, Village		1,260
Sherburne, Killington Mountain		4,241
Sherburne, East Mountain		2,812
Sherburne, Little Pico Peak		3,134
Sherburne, North Sherburne		1,280
Sherburne, Pico Mountain		3,967
Sherburne, Pico Pond		2,200
Sherman, Whitingham		1,100
Shoreham, Village		396
Shoreham, Barnum Hill		496
Shoreham, Cream Hill		420
Shoreham, Cudding Hill		500
Shoreham, Delano Hill		360
Shoreham, East Shoreham		276
Shoreham, Larabees Point		140
Shoreham, Pinnacle		655
Shoreham, (Shoreham Center)		280
Shoreham, Sisson Hill		517
Shrewsbury, Village		1,640
Shrewsbury, Cold River		1,500
Shrewsbury, Comtois Hill		2,020
Shrewsbury, Copperas Hill		1,861
Shrewsbury, Cuttingsville		1,000
Shrewsbury, North Shrewsbury		1,720

Locality	Authority	Altitude
Shrewsbury, Robinson Hill		2,779
Shrewsbury, Round Hill		1,660
Shrewsbury, Shrewsbury Peak		3,720
Shrewsbury, Shrewsbury Pond		1,457
Shrewsbury, Smith Peak		3,226
Shrewsbury, Wilcox Hill		2,072
Silent Cliff, Hancock		2,460
Silver Lake, Barnard		1,305
Silver Lake, Georgia		783
Silver Lake, Leicester		1,241
Simonds Hill, Pawlet		1,240
Simondsville, Andover	N. S.	.....
Single Hill, Wells		1,120
Sisson Hill, Shoreham		517
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		571
Sodom Pond, Adamant		1,036
Somerset, Village		2,000
South Barre		750
South Dorset		940
South Duxbury		781
South, Fairlee, Station		431
South Franklin		372
Southgate Mountain, Bridgewater		1,740
South Halifax		840
South Hero, Village		140
South Hero, Allen Point		120
South Hero, east of Beach Bay		200
South Hero, west of Keeler Bay		240
South Hill, Stockbridge		2,000
South Hinesburg	B. M.	434
South Lincoln, Village		1,313
South Londonderry		1,020
South Lunenburg		860
South Newbury, Station		407
South Newfane		680
South Newport		1,387
South Northfield		839
South Peacham	Aneroid	1,000
South Pomfret	B. M.	736
South Poultney		690

Locality	Authority	Altitude
South Richford		800
South Royalton, Village	B. M.	502
South Ryegate, Station	M. & W. R. R. R.	724
South Shaftsbury, Town Hall	B. M.	754
South Shaftsbury, bridge	B. M.	711
South Starksboro		1,098
South Strafford		960
South Vernon Junction		240
South Vershire		1,550
South Walden	Aneroid	1,300
South Wallingford		580
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		2,307
Spaulding Hill, Poultney		1,620
Spoon Mountain, Middleton		2,030
Springfield, Village	B. M.	410
Springfield, Bloodsucker Pond		760
Springfield, Chestnut Hill		800
Springfield, Cobble Hill		1,240
Springfield, Dutton School		950
Springfield, Fairground		350
Springfield, Goulds Mill	B. M.	360
Springfield, Hardscrabble Corner		642
Springfield, Hogan Hill		940
Springfield, Pond Hill		1,120
Springfield, Parker Hill School		940
Springfield, Pudding Hill, north		1,300
Springfield, Randall Hill		960
Springfield, Rattlesnake Hill		1,060
Springfield, River School		340
Springfield, Skitchiwaug Mountain, north		920
Springfield, Skitchiwaug Mountain, south		640
Springfield, Spencer School		500
Spring Grove Camp Grounds		408
Spruce Mountain, Arlington		2,510
Spruce Peak, Arlington		3,060
Spruce Knob, Poultney		2,220
Spruce Pond, Orwell		680
Spruce Top, Pawlet		1,378
Stacy Mountain, Wardsboro		1,935
Stamford, Village	B. M.	1,131

Locality	Authority	Altitude
Stamford, Bare Hill		2,240
Stamford, Hoosac Mountain		3,014
Stamford, Mud Pond		2,230
Stamford, Stamford Meadow		2,180
Stamford, Stamford Pond		2,380
Stamford, Sucker Pond		2,260
Stannard	N. S.	.....
Standing Pond, Sharon		1,380
Stark Mountain, Fayston		3,585
Starksboro, Village		612
Starksboro, Brown Mountain		2,300
Starksboro, East Mountain		1,520
Starksboro, Gore School		1,144
Starksboro, High Knob		1,320
Starksboro, Hillsboro Mountain		2,540
Starksboro, Jerusalem		1,495
Starksboro, Jerusalem School		1,340
Starksboro, No. 11 School		1,640
Starksboro, Norton Hill		2,040
Starksboro, Rockville		535
Starksboro, Shaker Mountain		1,920
Starksboro, South Starksboro		1,098
Sterling Mountain (Madonna Peak)		3,668
Sties Mountain, Sudbury		1,220
Stillwater Swamp, Barton		1,300
Stimson Mountain, Bolton		1,900
Stockbridge, Village		840
Stockbridge, Gaysville	B. M.	661
Stockbridge, Mount Pleasant School		841
Stockbridge, Notown		1,200
Stockbridge, Riverside		750
Stockbridge, Sable Mountain		2,691
Stockbridge, South Hill		2,000
Stockbridge, Station	B. M.	734
Stockbridge, Stony Brook School		963
Stockbridge, Vulture Mountain		1,520
Stone Hill, Norwich		1,680
Stowe, Village		723
Stowe, Lower Village		685
Stowe, Barnes Camp		1,550
Stowe, Bingham Falls	B. M.	1,300
Stowe, Brownsville School	B. M.	1,100
Stowe, Brush Hill		1,140
Stowe, Cady Hill		1,140
Stowe, Edson Hill School		1,200

Locality	Authority	Altitude
Stowe, Hogback Mountain		3,420
Stowe, Luce Hill		1,660
Stowe, Luce Hill School		1,134
Stowe, Mansfield Mountain, Forehead		3,920
Stowe, Mansfield Mountain, Hotel		3,849
Stowe, Mansfield Mountain, Nose		4,060
Stowe, Mansfield Mountain, Chin (this is in Underhill)		4,393
Stowe, Moscow		1,640
Stowe, North Hill		1,660
Stowe, North Hollow School		957
Stowe, Pinnacle		2,240
Stowe, Pucker Street School		738
Stowe, Round Top		1,760
Stowe, South Hollow School		1,096
Stowe, Spruce Peak		3,320
Stowe, Sterling Pond		3,060
Stowe, Sunset Hill		1,220
Stowe, Stowe Pinnacle		2,240
Stowe, Taber Hill		1,220
Stowe, Taft Lodge		3,650
Stowe, Toll House	B. M.	1,361
Stowe, West Branch		764
Stowe, West Hill School		1,137
Strafford, Village		960
Strafford, Cooks Hill		1,685
Strafford, Copper Flat		860
Strafford, Copperas Hill		1,060
Strafford, Davison Hill		1,740
Strafford, Grannyhand Hill		1,560
Strafford, Kibling Hill		1,424
Strafford, McMaster Hill		1,980
Strafford, Miller Pond		1,340
Strafford, Morrill Mountain		1,702
Strafford, Old City		1,220
Strafford, Richardson Hill		1,715
Strafford, South Strafford		950
Strafford, Whitcomb Hill		1,859
Strawberry Hill, Richford		2,406
Stratton, Village		1,870
Stratton, Grout Pond		2,225
Stratton, Stratton Mountain		3,859
Stratton, Stratton Pond		2,470
Styles Peak, Peru		3,404
Sucker Pond, Stamford		2,260
Sudbury, Village		572

Locality	Authority	Altitude
Sudbury, Burr Pond		512
Sudbury, Government Hill		1,075
Sudbury, High Pond		1,028
Sudbury, Hinckum Pond		717
Sudbury, Horton Pond		484
Sudbury, Huff Pond		772
Sudbury, Hyde Manor		420
Sudbury, Stiles Mountain		1,220
Sugar Hill, Goshen		2,091
Sugar Hill, Derby		1,540
Sugar Hill, Richford		2,543
Sugar Loaf Mountain, Underhill		2,979
Sugar Loaf Mountin, Warren		2,120
Sugar Loaf Mountain, Westfield		2,543
Summit Station, Mt. Holly		1,500
Summit Siding	C. P. R. R.	1,377
Sunderland, Village		649
Sunderland, Beebe Pond		2,280
Sunderland, Bourne Pond		2,520
Sunderland, Branch Pond		2,620
Sunderland, Catamount Cobble		2,360
Sunderland, Chiselville		740
Sunderland, East Kansas		940
Sunderland, Kansas		840
Sunderland, Kelley Stand		2,180
Sunderland, Lost Pond		2,640
Sunderland, Lye Brook Meadow		2,600
Sunderland, McIntyre		2,060
Sunderland, The Burning		2,607
Sunderland, Whetstone Bluff		2,200
Sunset Hill, Salisbury		925
Sunset Hill, Stowe		1,220
Sunset Lake, Benson		503
Sunset Lake, Brookfield		1,272
Swanton, Village, Park		155
Swanton, Clark Point		100
Swanton, East Station		155
Swanton, Fonda Quarry		280
Swanton, Greens Corners		405
Swanton, Maquam		106
Swanton, School No. 2		300
Swanton, School No. 3		416
Swanton, School No. 4		480
Swanton, School No. 7		140
Swanton, School No. 8		183

Locality	Authority	Altitude
Swanton, School No. 11		118
Swanton, Skeels Corners		320
Swanton, Swanton Junction		200
Swanton, West, Station	B. M.	137
Swanton, West Swanton		100
Swearing Hill, Sandgate		2,040
Taber Hill, Stowe		1,220
Tabor Mountain, Peru		3,584
Tadmer Hill, Pawlet		1,660
Taftsville, Woodstock	B. M.	668
Talcville, Rochester		820
Tarbelleville, Mt. Holly		1,560
Terrible Mountain, Andover, east peak		2,844
Texas Hill, Hinesburg		1,580
The Ball, Arlington		2,715
The Burning, Sunderland		2,607
The Island, Weston		1,230
The Ledge, Cornwall		380
Thersher Hill, Braintree		2,040
Thetford, Village, center		600
Thetford, Campbells Corner		740
Thetford, Center Hill		1,593
Thetford, Childs Hill		1,300
Thetford, Gove Hill		1,362
Thetford, Hubbard Hill		1,082
Thetford, Post Mills		700
Thetford, Preston Hill		1,480
Thetford, Rices Mills		620
Thetford, Station		480
Thetford, Swaney Bean		1,300
Thetford, Tug Mountain		1,893
Thetford, Union Village		440
Thistle Hill, Pomfret		2,000
Thompsons Point, Charlotte		140
Thousand Acre Hill, Chittenden		2,400
Thunder Head, Hancock		1,260
Tice, Holland		1,140
Tillotsons Mills, Lowell		1,340
Tinmouth, Village		1,263
Tinmouth, Clarke Mountain		2,040
Tinmouth Mountain, north peak		2,160
Tinmouth Mountain, south peak		2,827
Tinmouth Pond		1,200
Tinmouth, The Purchase		2,544
Topsham, Village	N. S.	.....

Locality	Authority	Altitude
Town Hall, Pawlet		1,320
Town Hall, Poultney		1,100
Townshend, Village	N. S.	.....
Troy, Village, Brocks Store		764
Troy, Big Falls		560
Troy, County Road School		650
Troy, East Hill School		960
Troy, Hitchcock School		999
Troy, North Troy	B. M.	605
Troy, Phelps Falls	B. M.	754
Troy, River Road School		650
Troy, Warner Hill		1,180
Troy, West Road School	B. M.	760
Trumbull Mountain, Shaftsbury		1,600
Tug Mountain, Thetford		1,893
Tunbridge, Village		640
Tunbridge, Brocklebank Hill		2,120
Tunbridge, Curtis Hill		1,561
Tunbridge, East Hill		1,540
Tunbridge, Goodwin Hill		1,380
Tunbridge, North Tunbridge		780
Tunbridge, Old Hurrican Hill		1,910
Tunbridge, Rae School		1,143
Tunbridge, School No. 11		1,180
Tunbridge, School No. 19		810
Tunbridge, South Tunbridge		542
Tunbridge, The Pinnacle		1,160
Tunbridge, Tunbridge Hill, north peak		1,940
Tunbridge, Tunbridge Hill, south peak		1,700
Tunbridge, Whitney Hill		1,260
Tunbridge, Williams Hill		1,940
Twin Ponds, Brookfield		1,208
Turkey Hill, Northfield		1,900
Tyson, Plymouth	N. S.	.....
Underhill, Village, Center		796
Underhill, Village, Flats	B. M.	706
Underhill, Creek School		752
Underhill, English Settlement School		1,130
Underhill, Flynn Hill		1,920
Underhill, Governors Rights School		1,080
Underhill, Halfway House, Mansfield		2,142
Underhill, Harvey School		1,200
Underhill, Hedgehog Hill		1,560
Underhill, Irish Settlement School		774
Underhill, McClean Hill		1,440

Locality	Authority	Altitude
Underhill, Macomber Mountain, south peak		1,560
Underhill, Macomber Mountain, north peak		1,140
Underhill, Metcalf Hill		1,400
Underhill, Mount Clarke		3,160
Underhill, Morse School		1,040
Underhill, North Underhill		860
Underhill, No. 13 School		913
Underhill, Poker Hill School		1,080
Underhill, Putnam Hill		1,040
Underhill, River Road School		746
Underhill, Round Top Mountain		337
Underhill, Stevensville School		1,148
Underhill, Sugar Loaf Mountain		2,979
Union Village, Thetford		440
Upper Graniteville		1,500
Vail Ridge, Pomfret		1,440
Vergennes, Stevens House		235
Vergennes, Bridge over Otter Creek		140
Vergennes, R. R. Station	B. M.	203
Vernon, Village		270
Vernon, Center		290
Vernon, Lily Pond		400
Vershire, Village		1,150
Vershire, Colton Hill		2,412
Vershire, Copperfield		980
Vershire, Eagle Ledge		1,859
Vershire, Gilman Hill		2,065
Vershire, Goodhue Ledge		1,820
Vershire, Mill Village		1,040
Vershire, Patterson Mountain		2,321
Vershire, South Vershire		1,560
Vershire, Vershire Center		1,700
Victory, Village	N. S.	.....
Waitsfield, Village	B. M.	698
Waitsfield, Bald Mountain		2,596
Waitsfield, East School		1,151
Waitsfield, Irasville		789
Waitsfield, Kew Hill		1,920
Waitsfield, Scrag Mountain		2,928
Waitsfield, South School		1,240
Waitsfield, Waitsfield Common		1,073
Waitsfield, Waitsfield Gap		2,143
Waits River, Topsham	N. S.	.....
Walker Pond, Coventry		973
Walden, Station	St. J. & L. C. R. R.	1,656

Locality	Authority	Altitude
Wallace Ledge, Castleton		960
Wallingford, Village		580
Wallingford, Bear Mountain		2,262
Wallingford, Button Hill		2,040
Wallingford, East Station		1,220
Wallingford, East Wallingford		1,240
Wallingford, Fox Pond		600
Wallingford, Green Hill		1,213
Wallingford, Little Pond		1,820
Wallingford, South Wallingford		620
Wallingford, Wallingford Pond		2,157
Wallingford, White Rocks		2,662
Wallis Pond, Canaan		1,300
Walnut Hill, Danby		1,546
Waltham, Village		540
Waltham, Buck Mountain		927
Wantastiquet Mountain, Weston		1,384
Wardsboro, Village		980
Wardsboro, Bucketville		1,100
Wardsboro, South Wardsboro		1,600
Wardsboro, Stacy Mountain		1,935
Wardsboro, West Wardsboro		1,360
Warner Hill, Troy		1,180
Warren, Village, near the Post Office	B. M.	893
Warren, Brown School		1,115
Warren, Burnt Mountain		2,760
Warren, Cutts Peak		4,060
Warren, Double Top Mountain		1,820
Warren, East Warren	B. M.	1,395
Warren, Lincoln Cap		2,424
Warren, Lincoln Peak		4,013
Warren, Mount Ellen		4,135
Warren, Nancy Hanks Mountain		3,840
Warren, No. 5 School		1,498
Warren, No. 7 School		1,500
Warren, Robinson School		800
Warren, Roxbury Gap, highest part		2,400
Warren, South Hill School		1,440
Warren, South Olive School	B. M.	1,349
Warren, Sugar Loaf Mountain		2,120
Warren, Warren Pinnacle		1,700
Warrens Gore, Middle Mountain		2,660
Warrens Gore, Norton Pond		1,335
Warrens Gore, Summit Station	B. M.	1,378
Washington, Village	N. S.	.....

Locality	Authority	Altitude
Waterbury, Village	B. M.	425
Waterbury, Barnes Hill		1,200
Waterbury, Blush Hill		1,080
Waterbury, Blush Hill School		880
Waterbury, Bolton Falls		380
Waterbury, Colbyville		594
Waterbury, East School		700
Waterbury, Gregg Hill		1,100
Waterbury, Kneeland Flats		639
Waterbury, Kneeland Flats School		700
Waterbury, Little River School		500
Waterbury, Loomis Hill		1,340
Waterbury, Loomis Hill School		1,220
Waterbury, Mill Village		500
Waterbury, Owls Head Mountain		1,600
Waterbury, Perry Hill		1,320
Waterbury, Perry School		1,020
Waterbury, Post Office		425
Waterbury, Ricker Mountain		3,401
Waterbury, Ricker School		1,500
Waterbury, Waterbury Center	B. M.	655
Waterbury, Willey Hill		1,220
Waterbury, Woodward Mountain		3,100
Waterford, Village	N. S.	.....
Waterville	N. S.	.....
Weathersfield, Amsden		596
Weathersfield, Ascutney Village	B. M.	412
Weathersfield, Bow		362
Weathersfield, Camp Hill, north peak		1,380
Weathersfield, Camp Hill, south peak		1,560
Weathersfield, Center	B. M.	1,194
Weathersfield, Cook Pond		1,075
Weathersfield, Goulden Ridge		1,380
Weathersfield, Goulds School		800
Weathersfield, Little Ascutney Mountain		1,740
Weathersfield, Luther School		860
Weathersfield, Nelsons Corner		674
Weathersfield, Pearson Peak		1,668
Weathersfield, Pikes Peak		1,380
Weathersfield, Pine Hill		955
Weathersfield, Springfield Reservoir		960
Weathersfield, Upham School		920
Weathersfield, Weathersfield Bow		352
Websterville, Barre		1,400
Wells, Village		502

Locality	Authority	Altitude
Wells, Coy Mountain		2,060
Wells, East Wells		1,080
Wells, Fan Hill		1,731
Wells, Lincoln Hill		1,300
Wells, Little Pond		477
Wells, Moosehorn Mountain		2,780
Wells, Northeast Mountain		2,125
Wells, Pond Mountain, north peak		1,518
Wells, Pond Mountain, south peak		1,360
Wells, St. Catherine, Lake		477
Wells, St. Catherine Mountain		1,060
Wells, Single Hill		1,240
Wells, The Pinnacle		1,940
Wells River, Village, Hales Tavern	Aneroid	395
Wells River, Station	M. & W. R. R. R.	435
Wells River, top of bolt in signal base	B. & M. R. R.	402
Wenlock, Station	C. N. R.	1,149
West Addison		100
West Barnet	N. S.	.....
West Berkshire	B. M.	545
West Bolton	B. M.	991
West Brattleboro	B. M.	443
West Bridgewater	B. M.	1,058
West Burke, Station	B. & M. R. R.	.....
West Castleton		480
West Charleston	B. M.	1,028
West Concord	St. J. & L. C. R. R.	876
West Corinth	N. S.	.....
West Cornwall		480
West Danville, Station	St. J. & L. C. R. R.	1,496
West Dover		1,720
West Dummerston, Church		400
West Enosburg, Ovitts Store		440
West Enosburg, Station		462
West Fairlee, Village		760
Westfield, Village	B. M.	825
Westfield, Hazen Notch		1,700
Westfield, Jay Peak		3,861
Westfield, North Hill School		1,105
Westfield, Phillips Pond		1,000
Westfield, Strawberry Hill		2,400
Westfield, Sugar Loaf Mountain		2,543
Westfield, Trumpas School		980
Westford, Village	B. M.	467
Westford, Bald Hill		1,240

Locality	Authority	Altitude
Westford, Bowmans Corners		740
Westford, Brookside School		510
Westford, Cloverdale	B. M.	641
Westford, Duffy Hill		1,220
Westford, Jack Lot Hill		1,460
Westford, King School		880
Westford, Milton Pond		834
Westford, No. 2 School		600
Westford, No. 11 School		1,200
Westford, Oak Hill		1,140
Westford, Osgood School		760
Westford, Prospect Hill		1,040
Westford, Stewart Hill		1,564
Westford, Westford Center	B. M.	467
Westford, Westford Pond		790
West Glover	N. S.	.....
West Halifax		1,160
West Hartford, Station	B. M.	420
West Haven, Village		380
West Haven, Cold Spring		120
West Haven, Forbes Hill		520
West Hill, Worcester	N. S.	.....
West Jamaica		1,540
West Lincoln		890
West Marlboro		1,780
West Milton	B. M.	114
Westminster, Village		314
Westminster, Bald Hill		760
Westminster, Cliff School		754
Westminster, Gageville		300
Westminster, Grout Station		300
Westminister, Hedgehog Hill		1,040
Westminster, Kurn Hattin Home		412
Westminster, Pine Branch School		560
Westminster, R. R. Station		300
Westmore, Bald Mountain		3,315
Westmore, Goodwin Mountain, north peak		2,935
Westmore, Goodwin Mountain, south peak		2,614
Westmore, Hinton School		1,960
Westmore, Jobs Mountain		2,800
Westmore, Jobs Pond		1,950
Westmore, Lake View School		1,300
Westmore, Lake Willoughby		1,169
Westmore, Long Pond		1,835
Westmore, main road, north end of the lake	B. M.	1,191

Locality	Authority	Altitude
Westmore, Mud Pond		1,780
Westmore, Nigger Pond		1,825
Westmore, Songadeewa Camp		1,304
Westmore, Valley Mountain		1,395
Westmore, Village		1,200
West Mountain, Shaftsbury		2,022
West Newbury	N. S.	.....
West Norwich		1,140
Weston, Village		1,300
Weston, Cobble Hill		1,907
Weston, Markham Mountain		2,481
Weston, Peabody Hill		2,787
Weston, The Island		1,160
West Pawlet, Village		500
West Rupert, Village		760
West Rutland, Village		500
West Salisbury	B. M.	420
West Swanton	B. M.	137
West Topsham	N. S.	.....
West Townshend	N. S.	.....
Westville, Groton	N. S.	.....
Westville, Groton	N. S.	.....
West Wardsboro		1,360
West Woodstock	B. M.	713
West Windsor, Village	N. S.	.....
West Windsor, Ascutney Notch		1,049
West Windsor, Brownsville	B. M.	679
West Windsor, Cummings Hill		1,300
West Windsor, Pierson Peak		1,668
West Windsor, Ralph School		1,240
West Windsor, Sheddville		1,176
Weybridge, Village		180
Weybridge, Center		420
Wheelock	N. S.	.....
White River Junction, Station		340
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 Rocks Mountain, Goshen		3,307
White Rocks Mountain, Worcester		3,220
White Rocks Mountain, Wallingford		2,662
Whitingham, Village		1,600
Whitingham, Davis Bridge		1,340
Whitingham, Jacksonville		1,400

Locality	Authority	Altitude
Whitingham, Sadagwa Pond		1,660
Whitney Hill, Tunbridge		1,280
Wickopee Hill, Dummerston		1,656
Wilcox Hill, Benson		688
Wilcox Hill, Shrewsbury		2,072
Wilcox Peak, Pittsfield		2,921
Wilder, Station		409
Wilder, Library	B. M.	430
Willey Hill, Waterbury		1,220
Williams Hill, Tunbridge		1,940
Williamstown, Village	B. M.	872
Williamstown, Baptist Street School		1,500
Williamstown, Boyce School		1,100
Williamstown, Clagston School		1,669
Williamstown, Cutter Pond		920
Williamstown, East Hill Cemetery		1,260
Williamstown, Jackson Corners		1,487
Williamstown, Lighthouse Hill		1,857
Williamstown, Lynde School		1,285
Williamstown, Martin School		1,094
Williamstown, Mount Pleasant		2,048
Williamstown, No. 13 School		1,666
Williamstown, Rood Pond		1,306
Williamstown, Staples Pond		900
Williamstown, South Hill School		1,400
Williamstown, Upper Graniteville		1,487
Williamsville, Village, Newfane		580
Williamsville, Station		400
Williston, Village, Methodist Church	B. M.	501
Williston, Brownell Mountain		820
Williston, Hinesburg Pond		684
Williston, Muddy Brook Hill, road at top		308
Williston, North Williston	B. M.	305
Willoughby Lake, Westmore		1,169
Wilmington, Village		1,580
Wilmington, East Wilmington		1,860
Wilmington, Haystack Pond		2,860
Wilmington, Haystack Mountain		3,462
Wilmington, Ray Pond		1,860
Windham	N. S.	.....
Windsor, Village	B. M.	354
Windsor, Ascutney Mountain		3,144
Windsor, Bandstand in Park		360
Windsor, Clarke School		919
Windsor, Crystal Lake		383

Locality	Authority	Altitude
Windsor, Evarts School		325
Windsor, Horseback Ridge		740
Windsor, Lake Runneymede		322
Windsor, Mountain School		460
Windsor, R. R. Station	B. M.	354
Winooski, Village		200
Winooski, High School		240
Winooski, Main Street		200
Winooski, north end of bridge		136
Winooski, River, below the falls		107
Winooski, Station		200
Wolcott, Station	B. & M. R. R.	720
Wolcott, Town Hall	Aneroid	1,200
Woodbury	N. S.	.....
Woodford, Village		2,215
Woodford, Bald Mountain		2,865
Woodford, Beaver Meadows		2,240
Woodford, Big Pond		2,263
Woodford, Billings Pond		2,120
Woodford, Camp Meadows		2,340
Woodford, Hagar Hill		2,800
Woodford, Harmony Hill		2,325
Woodford, Lily Pond		2,620
Woodford, Little Pond		2,620
Woodford, Maple Hill		2,740
Woodford, Power House	B. M.	1,672
Woodford, Prospect Mountain		2,740
Woodford, The Elbow		2,587
Woodford, West Hollow, Camp Comfort		2,215
Woodlawn Mountain, Danby		3,072
Woodstock, Village	B. M.	705
Woodstock, Bailey Hill		1,600
Woodstock, Curtis Hollow School		1,166
Woodstock, English Mills		840
Woodstock, Fletcher Hill		1,840
Woodstock, Fletcher School		1,340
Woodstock, Hurricane Hill		1,180
Woodstock, Lincoln Bridge		758
Woodstock, Meetinghouse Hill		1,560
Woodstock, Mount Peg		1,040
Woodstock, Pelton School		1,092
Woodstock, South Woodstock	B. M.	1,055
Woodstock, Taftsville	B. M.	668
Woodstock, The Pogue		1,160
Woodstock, Town Farm		1,160

Locality	Authority	Altitude
Woodstock, Walker School		1,500
Woodward Mountain, Waterbury		3,100
Worcester, Village	B. M.	780
Worcester, Dumpling Hill		1,920
Worcester, Hampshire Hill School		1,262
Worcester, Hobart Mountain		1,960
Worcester, Hunt School		765
Worcester, Long Meadow Hill		2,020
Worcester, Minister Brook School		900
Worcester, Mt. Hunger		3,554
Worcester, Mt. Worcester		3,286
Worcester, West Hill		2,380
Worcester, Wheeler School		1,060
Worcester, Worcester Ponds		1,120
Worth Mountain, Hancock		3,300
Wrightsville, Montpelier		615
Yantz Hill, Richmond		1,060
Zion Hill, Hubbardton		1,229

REPORT

OF THE

STATE GEOLOGIST

ON THE

MINERAL INDUSTRIES AND GEOLOGY

OF

VERMONT

1927-1928

SIXTEENTH OF THIS SERIES

GEORGE H. PERKINS
State Geologist

FREE PRESS PRINTING CO., BURLINGTON, VT.

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Winooski, High School		240
Winooski, Main Street		200
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Wolcott, Station	B. & M. R. R.	720
Wolcott, Town Hall	Aneroid	1,200
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Woodford, Village		2,215
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Woodford, Prospect Mountain		2,740
Woodford, The Elbow		2,587
Woodford, West Hollow, Camp Comfort		2,215
Woodlawn Mountain, Danby		3,072
Woodstock, Village	B. M.	705
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THE GEOLOGY AND PETROGRAPHY OF READING, CAVENDISH, BALTIMORE AND CHESTER, VERMONT

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Syracuse University
Syracuse, N. Y.

INTRODUCTION

The report upon the Geology and Petrography of Reading, Cavendish, Baltimore and Chester, Vermont, is of necessity brief. The time available for detailed field work and the petrographic study in the laboratory of many microscopic slides has been altogether too limited to bring out all that might be desirable as to structure and mineralogical composition of the terranes involved. The report must be regarded as one of progress in the solution of the many intricate problems dealing with the geology of eastern Vermont. It is hoped that there will be presented clearly the results of new field work and the new petrographic studies in a field hitherto undescribed, yet closely folded, faulted and invaded by both acid and basic intrusives. The mode of origin cannot be ascertained with certainty in some instances even with careful petrographic study. It is possible to determine what the minerals in the rocks now are, but what were they originally? The stratigraphic relation is at times uncertain because a large part of the area involved is drift covered and wooded. It is difficult to determine the actual age of some of the formations involved because of the absence of fossils in the pre-Ordovician terranes. The absence of topographic maps has impeded progress in mapping the areal distribution of the different terranes. It is, however, a source of satisfaction to know that the Ludlow quadrangle is being mapped this summer by C. H. Davey of the U. S. Geological Survey and his assistants. This quadrangle embraces most of the area involved in this report. A small part of Reading is included in the Woodstock quadrangle.

The townships of Reading, Cavendish, Baltimore and Chester are situated some fifty miles southeast of the geographic center of the state. The northern part of Reading is approximately north latitude 43°, 33′ and the southern part of Chester 43°, 14′. It furthermore lies between meridian 72°, 30′ and 72°, 45′ west of Greenwich. The townships are listed in the order of their

geographic position from north to south, as this is the order in which the field work was executed.

There are five definite reasons for the selection of Reading, Cavendish, Baltimore and Chester for field work: (1) These townships lie south 10 degrees west of Woodstock whose geology and petrography was published in the Biennial Report of the State Geologist for 1925-26. (2) They make the work continuous in a southerly direction in the eastern half of the State. (3) They fall in the line of the erosional unconformity between the Ordovician and the pre-Ordovician, probably Cambrian, formations on the eastern side of the Green Mountains. This unconformity, as will be shown later in this report, dies out in Chester. (4) The presence of both acid and basic intrusives whose mineral composition has never been worked out and published. (5) The fact that no detailed field work has ever been done and no petrographic study ever made of either the sedimentaries or their associated intrusives.

The author traversed a considerable part of this area in reconnaissance work during the summer of 1895. The detailed field work in Reading and Cavendish was done during the summers 1926 and 1927. The detailed work in Baltimore and Chester was executed during the summer of 1928. Some field work was also carried out in west Windsor, Weathersfield and Springfield on the east, Grafton and Windham on the south and in Andover, Ludlow and Plymouth on the west. Furthermore some field work was carried out in the Brattleboro quadrangle to ascertain how the terranes in eastern Vermont tied up with those in Massachusetts as described by B. K. Emerson in his "Geology of Massachusetts and Rhode Island." Professor L. W. Currier of Purdue University, Lafayette, Indiana, has been with the author a part of the time in the field and worked out a detailed petrographic study of some of the microscopic slides.

The field relations of the different terranes in Reading, Cavendish, Baltimore, and Chester are often difficult to determine. The townships as a unit are hilly, glaciated and in part densely wooded. The latter condition holds particularly true of the western part of Reading and Chester where many roads and farms are abandoned. With a heavy glacial till and a dense growth of underbrush actual contacts between the different formations are extremely difficult to find.

Two areal maps showing the distribution of the different terranes together with a cross section in Chester accompanies this report as Figures A and B. The uncertainty of the planes of bedding in many instances renders a complete structural map difficult of correct interpretation and, therefore, it is omitted. The area involved in this report has always been mapped as purely

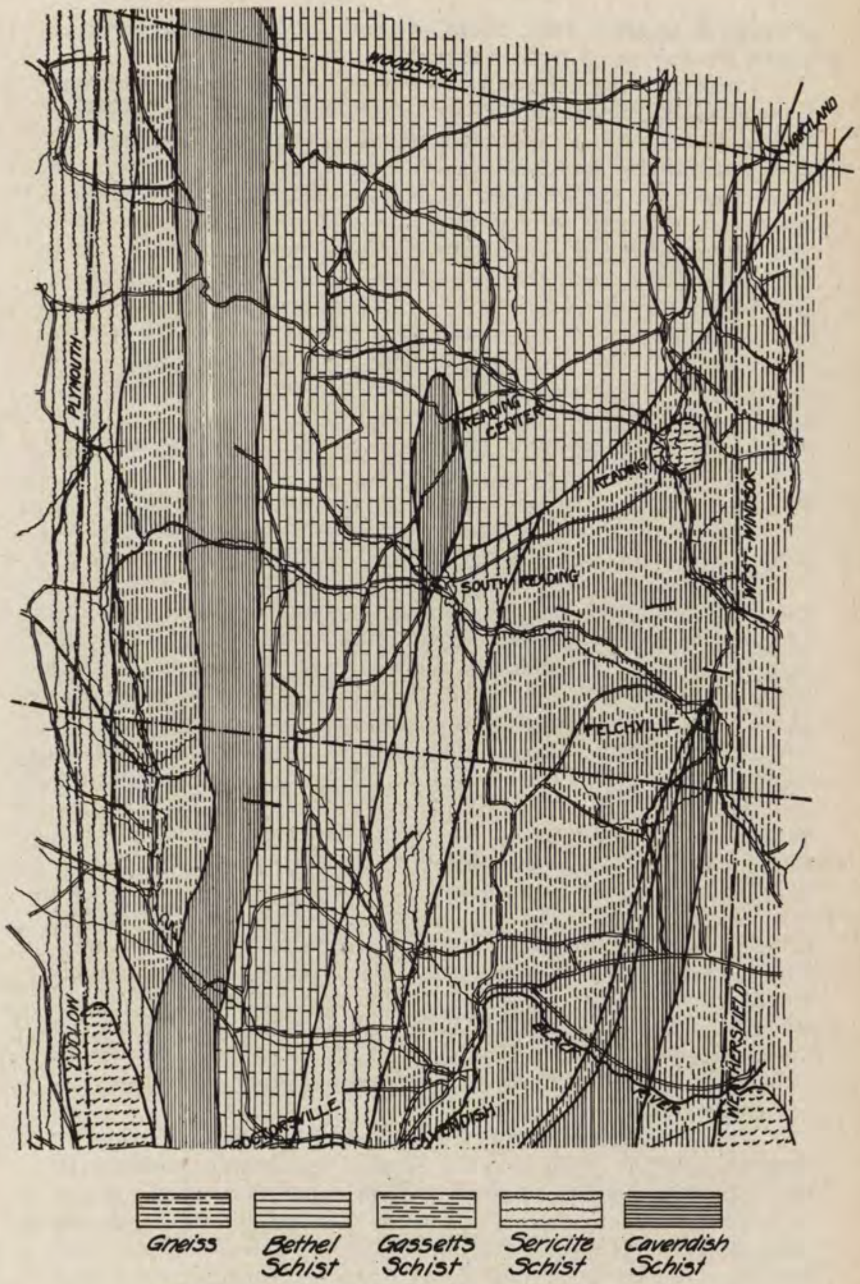

FIGURE 19a.—Areal map of Reading and Cavendish. Horizontal scale, 1 inch = 1 mile.

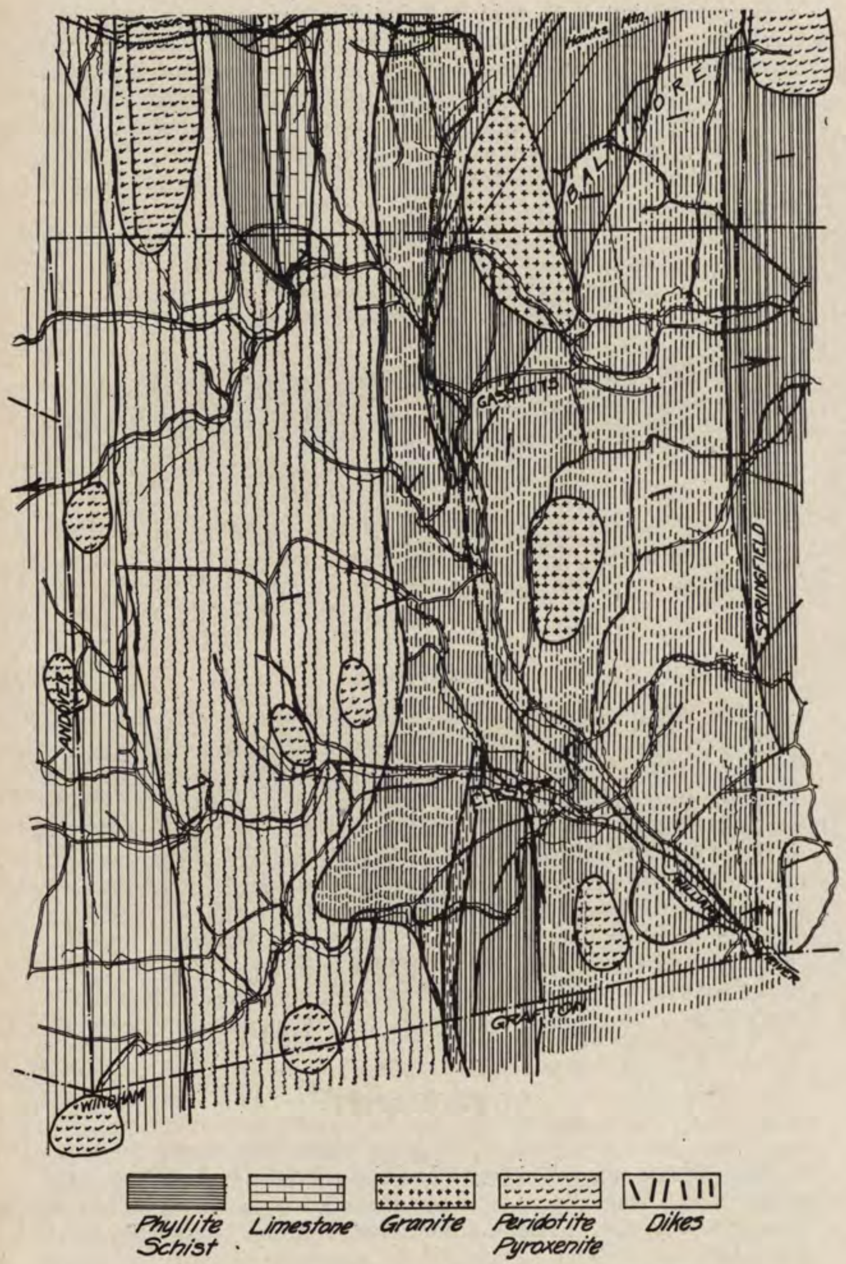

FIGURE 19b.—Areal map of Baltimore and Chester. Horizontal scale, 1 inch = 1 mile.

sedimentary, but both acid and basic intrusives have been discovered and so far as possible their location will be shown on the areal map. It is interesting to note here that many of the rocks considered by the earlier geologists to be highly metamorphosed sediments are now definitely proved to be granite gneisses. The presence of a large amount of microcline showing the characteristic grating structure in the microscopic slides substantiates this view. (Figure 20.)

Several new rock samples have been collected, trimmed to regulation size, 3 x 4 inches, and placed in the museum at Montpelier. This brings the number of State samples collected in the eastern half of Vermont up to nine hundred fifty.

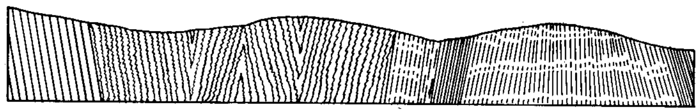

FIGURE 20.— Cross section in Chester.

Two hundred samples of rocks have been collected from which microscopic slides have been made for petrographic study. Without this type of research work it is impossible to correctly translate the results of field investigations.

DRAINAGE

The chief drainage of the area involved in this report is effected by two rivers. The northernmost of these two streams is the Black River which rises in Plymouth, flows in a southerly direction through Plymouth and Ludlow, in an easterly direction through Proctorsville and Cavendish and then in a southeasterly direction through Weathersfield and Springfield. It empties into the Connecticut River in Springfield. The southernmost stream is Williams River which rises in Andover, flows in a southeasterly direction through Chester and Rockingham and empties into the Connecticut River a little north of Bellows Falls. Each of these rivers receives several small streams from both the north and the south sides. Many of them have only local names and need not be mentioned.

TOPOGRAPHY

There are two broad "U"-shaped valleys traversing the area covered by this report.The northernmost of these is the pre-glacial valley of the Black River which contains some of the most fertile farms in Vermont. The southernmost of these broad valleys is that of Williams River. Many of the numerous transverse valleys

are in part pre-glacial and in part post-glacial. Some of these valleys are very productive.

In the absence of topographic maps it is hard to give altitudes with accuracy. Several hills in Reading attain an altitude of between 1,500 and 2,000 feet. The hill south of Mecawee Pond in the northwest corner of Reading has an altitude of 1,900 feet. Directly south of this hill an altitude was recorded of 2,010 feet. On Reading Hill near the southern boundary of the Woodstock quadrangle the altitude is 2,450 feet. Hawks Mountain in Baltimore and Cavendish attains an altitude of 2,040 feet. Steadman Hill in the western part of Chester is 2,400 feet in height. In Andover near the Andover-Chester town line the altitude is 1,830 feet. Butternut Hill near the central part of Chester is 1,670 feet in height. The altitude of the railway tracks in front of the station at Ludlow is 1,064 feet. Proctorsville, 928 feet. Cavendish 929 feet, Chester, 599 feet and the U. S. Bench Mark on the lowest step at the Fullerton Inn in Chester is 623 feet. The lowest altitude found in Chester is 520 feet. This is at the point where the Williams River leaves the Ludlow Quadrangle. The lowest altitude on the quadrangle is 440 feet. It is located at the point where the Black River passes to the Claremont Quadrangle. The topography of Reading, Cavendish, Baltimore and Chester as a unit is rugged and may be regarded as in the stage of late maturity.

GLACIATION

The townships of Reading, Cavendish, Baltimore and Chester are 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 Reading and Chester where the hills are densely wooded. Many of the streams in these areas have not yet cut their channels down to bed rock. Sometimes a stream can be followed for several miles without finding a single outcrop of rock in its original place. The beds of the streams, however, bear many glacial boulders.

Evidences of glaciation and the general direction of the ice movement can be found in the striations still remaining on the more resistant rocks. Well exposed outcrops of nearly pure white vein quartz and the broad dikelike quartz outcrops are particularly prone to furnish this evidence. The Cambrian quartzites as they appear in the higher altitudes have furnished many good examples of glacial grooving. The variations in directions recorded range from due south to south 20 degrees east and south 20 degrees west. In the northern part of Chester definite glacial groovings were recorded with strike south 30 degrees east but this appears to be local.

Perhaps the most interesting feature in the distribution of glacial débris in Cavendish is the filling of an old river bed of Black River. With the recession of the ice mantle the waters of Black River began cutting out of solid rock what is known as Cavendish Gorge. Its length is approximately one-half mile and the fall in this distance one hundred eighty-five feet. Its depth is from fifty to seventy-five feet and its walls are nearly vertical. The gorge is cut in the Cavendish schist and Reading gneiss. At

FIGURE 21. Reading gneiss exposed in the washout at Cavendish Village, November 5, 1927.

the Cavendish entrance to the gorge a hydro-electric plant has been established. If this plant had not been constructed it is doubtful if there would have been any loss of buildings in Cavendish during the flood of November 4 and 5, 1927. As it was seven houses, four barns and three garages were washed away and the channel cut in and sand and gravel for a part of its distance is estimated to be one hundred feet in depth. The bed rock now exposed in this washout is the Reading gneiss. (See Figure 21.)

Another interesting feature is the presence of a glacial delta, just west of the village of Chester, eight hundred seventy feet in altitude. The base is six hundred forty feet in altitude above sea level. Therefore, the delta deposit is two hundred thirty feet in

height. The angle of repose is approximately thirty degrees. (See Figure 22.)

LAKES

There are only two small lakes or ponds in the area covered by this report. They are both of glacial origin and small. They are both in Reading. One of them is in the northwest corner of Reading and is known as Mecawee Pond. Directly to the northwest the mountains rise to 2,100 feet and to the southwest to 1,900

FIGURE 22.—Glacial Delta, Chester, height 230 feet.

feet. Around the lake it is densely wooded, and the scenery is picturesque.

The other small body of water is known as Reading Pond. It is situated in the extreme western part of Reading about midway between the north and south boundary lines. According to the topographic map known as the Woodstock quadrangle a part of this pond lies in Plymouth. This pond is also surrounded by mountains. Directly to the northeast of the pond the altitude is 2,185 feet, and directly to the northwest in Plymouth the altitude is 2,100 feet.

GEOLOGY AND PETROGRAPHY

The geology of Reading, Cavendish, Baltimore and Chester is intricate and complex. The correct interpretation of the geologic history of Chester appears more difficult than that of any other township in eastern Vermont. The sedimentaries in the four townships mentioned above consist of a series of highly folded and faulted metamorphics that are often cut by intrusives of more than one period of introduction. The sediments range in composition from quartzose marbles to quartzites with no trace of a lime content, and from shale or slate to highly chloritic and epidotic mica schists. In fact, some of the sediments may be so highly metamorphosed that it is extremely difficult to prove that they were not of igneous origin. The intrusives range from the very acid aplite, through granites, diorites and diabases to the ultra basic rock peridolite. In the petrographic laboratory the microscope under polarized light tells us what the individual constituents in both the sedimentary and igneous rocks now are but it does not always reveal with certainty the mineral composition of the original rock. In some instances what constituents have been subtracted and what added, and under what conditions various solutions were added we do not know. The sediments vary in age from the Cambrian to Ordovician. There is not positive evidence of any pre-Cambrian sedimentation in the area involved in this report nor is there any evidence of any sedimentary rock younger than Middle Ordovician. The intrusives also vary widely in age and range from the Cambrian to the Carboniferous, or possibly the Triassic.

A careful study of the field relations has been made to avoid the introduction of errors in the interpretation of geologic structure and areal distribution, but with the area drift covered, much of it wooded, and the absence of topographic maps, errors in interpretation are possible and areal distribution mapped subject to revision.

More than two hundred microscopic slides have been prepared for study in the petrographic laboratory. While the great majority of the slides have been made from the rocks in Reading, Cavendish, Baltimore and Chester a goodly number of slides have been prepared from rocks collected in adjacent townships. A detailed study of these slides has brought out several exceedingly interesting facts which may be listed as follows:

(1) A large decrease in the percentage of magnetite in the pre-Ordovician terranes. Magnetite was exceedingly abundant in the slides from Roxbury, Braintree, Randolph, Bethel and Rochester.

(2) A rapid increase in the feldspar content (albite) in the sericite schists and the sericitic quartzites. In the more northern areas feldspars have been sparingly present in the sericite schists save in contact with intrusives and wanting in the sericitic quartzites. The one striking exception to this rule is found in Roxbury near the Braintree-Roxbury town line.

(3) A rapidly increasing biotite content in the sericite schists so that the rock frequently becomes a biotitic sericite schist and at times a biotite schist.

(4) The feldspar of many of the igneous rocks appears to have been albitized or else the feldspar of the original intrusive was albite which has not been proved.

(5) The granites of the more southern townships are soda granites rather than potash granites like those of Barre.

(6) The abundance of microcline in the gneisses of wide distribution. This is regarded as one of the most important petrographic discoveries for microcline is a pyrogenetic mineral and not one of secondary origin developed in sediments. This proves a large area of gneisses to have been orginally microcline granites.

In much of the area involved in this report the stratigraphy has been determined by field relations. This was necessary for no fossil content has as yet been discovered in the pre-Ordovician terranes on the eastern side of the Green Mountains. In the northern townships, Reading and Cavendish, new beds of graptolites have been discovered. These diagnostic features are not abundant and many pieces of limestone have to be broken to find evidences of a graptolite content. Since no definite graptolites were found in Chester and since the western arm of the Ordovician limestones and phyllites does not extend south of the northwestern corner of Chester, in Smokeshire, a fuller account of the distribution of graptolites in eastern Vermont will be given under the caption of Paleontology.

ALGONKIAN

The Algonkian, or pre-Cambrian, terranes, do not occur in Reading, Cavendish, Baltimore and Chester. However, they do occur in Sherburne, Plymouth, Ludlow and Andover which townships lie to the west of those involved in this report. The Sherburne conglomerate which was discovered by the author of this report in 1892 and named by him the Sherburne conglomerate is post-Algonkian for it is flanked on the west by Algonkian gneiss and on the east by Cambrian schists. It carries pebbles and boulders up to one foot in diameter of quartzites, granites and gneisses of pre-Cambrian age now embedded in a Cambrian matrix. Some of the boulders were sheared into gneisses before the conglomerate was formed for the gneissoid parting of the boulders is often at a high angle with the cleavage planes of the schist which encases them. A good outcrop of this conglomerate can be seen about two miles southeast of north Sherburne at the head of the narrow valley leading down to Sherburne. This erosional unconformity has been followed southward to the

Massachusetts line and northward into the southwest corner of Rochester. Now that contour maps are available as an aid in detailed field work it would be a valuable piece of work to follow this break in the geologic history on the east side of the Green Mountains the entire length of the state and map in with accuracy the two formations so widely different in age.

CAMBRIAN

The term Cambrian as here used denotes 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 terranes from the Ordovician. That the terranes listed as Cambrian are pre-Ordovician is proved by the fact that they underlie all phases of the Irasburg conglomerate which constitutes the base of the Ordovician series in eastern Vermont. This inferior position has been followed in Vermont for one hundred and fifty miles, across the entire state and northward in Canada for two hundred miles.

That these terranes listed as Cambrian are post-Algonkian in age is proved by two facts: (1) They all overlie the Algonkian gneiss that flanks them on the west. (2) The lowest member of the group is a basal conglomerate, the Sherburne conglomerate.

The Cambrian formations consist of a series of highly feldspathic mica schists, feldspathic quartzites, chlorite schists, biotite schists, sericite schists and sericitic quartzites that were derived from the erosion of the Algonkian land mass, during Cambrian times. Terranes of Cambrian age appear in each township involved in this report; but Baltimore is regarded as entirely Cambrain save for its intrusives.

LOWER CAMBRIAN

The division of the Cambrian terranes into the Lower Cambrian and the Upper Cambrian may seem to some geologists purely arbitrary and without sufficient reason for such a classification. However, the author of this report has found from time to time in the more northern townships evidences of a conglomerate in the basal members of the Bethel chlorite schist. The most striking evidence of such a conglomerate was found by the author this summer in northern Windham, at Windham Four Corners, two miles north of Windham. Here, many of the circular quartz eyes are completely surrounded by the chlorite schist. If this is a true conglomerate it marks the base of the Upper Cambrian. The Lower Cambrian terranes consist of the Sherburne conglomerate, the Plymouth dolomite, a highly feldspathic mica schist, a feldspathic quartzite, the Pinney Hollow schist and the Ottauquechee schist which is largely a black phyllite with slaty parting. None of the above formations appear in Reading, Cavendish, Baltimore and Chester.

UPPER CAMBRIAN

The terranes here listed as Upper Cambrian consist of chlorite schists, biotite schists, muscovite schists, sericite schists and quartzites. These formations all occur in Reading, Cavendish, Baltimore and Chester although they do not all appear in Baltimore.

Before taking up the general discussion of the above named terranes several questions may legitimately be raised. (1) Was deposition continuous on the eastern side of the Green Mountains throughout Cambrian times? (2) Did deposition begin with the Sherburne conglomerate in Lower Cambrian time and cease with the Middle Cambrian? (3) Did deposition begin with the Upper Cambrian and cease with the uplift that came at the close of the Cambrian? (4) Is the Middle Cambrian entirely wanting east of the Green Mountains?

The great thickness of the Cambrian terranes would imply that deposition began in the Lower Cambrian time. The presence of an apparent conglomerate in the lower portion of the Bethel schist would imply that sedimentation was not continuous during Cambrian time. If this conjecture can be proved in subsequent field work in Windham and Townshend then it seems rational to assume that the break in the continuity of deposition came in Middle Cambrian time. It is unfortunate that no fossil content has as yet been found in the Cambrian series of eastern Vermont. The rocks are all very highly metamorphosed, closely folded and faulted. How much of the schistosity was introduced with the uplift that came at the close of the Cambrian is not known. The uplift was accompanied by the introduction of both acid and basic intrusions for these igneous rocks occur as boulders in the various phases of the Irasburg conglomerate which forms the base of the Ordovician series in eastern Vermont.

BETHEL SCHIST

The Bethel schist, which was so characteristic a terrane in the township of Bethel from which it derived its name, extends southward from Bethel through Barnard, Bridgewater, Plymouth, Ludlow, Andover, Chester, Windham, Newfane and Halifax to the Massachusetts state line. It is absent from Reading, Cavendish and Baltimore because the western town line of these townships does not fall far enough to the west to embrace this formation. In Chester it is a continuous terrane in the western part of the township.

The Bethel schists are fine grained, greenish, schistose, highly metamorphosed sedimentary rocks which are more or less intimately associated with chlorite and epidote. They are particularly characterized by numerous lenses, or eyes, and stringers of granular quartz. The quartz lenses, or eyes, vary in width from a small fraction of an inch up to five or six inches, and in length from an inch up to a foot or more. The smaller of these lenses sometimes suggest elongated quartz pebbles. Sometimes they cross the schistosity but more often they are elongated in the direction of the schistosity. The quartz in the lenses, or eyes, and in the stringers, is all of the same granular type.

In this formation in several townships to the north of Bethel where this rock was listed as a hydromica schist, there were often suggestions of a conglomerate but the presence of actual pebbles could not be proved. However, there is an outcrop at Windham Four Corners, two miles north of the village of Windham, in which some of the eyes of quartz are nearly, if not quite, devoid of elongation and are completely surrounded by the schistose material. This outcrop strikingly suggests a basal conglomerate. It would require much detailed field work in Windham to prove the point.

The average strike of the Bethel schist is approximately north ten degrees east, but wider variations both to the east and the west have been observed. In Chester the strike is practically parallel with the Chester-Andover town line, north ten degrees east. In the eastern part of this formation the dip is invariably to the east. This holds particularly true in the western part of Chester and the eastern part of Andover and Ludlow. In the northeastern part of Andover the dip varies from 65 to 70 degrees east. In the northwestern part of Chester in the valley of Potash Brook the dip is east and the outcrop is very garnetiferous. This garnetiferous phase also appears in the extreme eastern part of Andover along the road from Chester to Peaseville. In the northern part of Windham the dip is from 85 degrees east to vertical. In a few instances high westerly dips were recorded but these appear to be purely local.

The Bethel schists are unquestionably older than the members of the Missisiquoi group for these latter terranes lie conformably upon the eastern flank of the Bethel schist in all the outcrops from Bethel to Windham. In the extreme northeastern part of Andover there is a belt of very dark colored schist that breaks with a splintery fracture like the Ottauquechee schist of E. L. Perry or the Wolcott schist in the Lamoille valley. If this outcrop is the Ottauquechee schist then there has been a complete overthrust of a part of the Bethel schist over a part of the Ottauquechee terrane. The author believes, however, that this black splintery bed represents only a local phase of the Bethel schist. The Bethel schist is regarded as forming the base of the Upper Cambrian in eastern Vermont. The discovery in Windham this summer appears to substantiate this theory.

CHLORITE SCHIST

There are narrow beds of chlorite schist that usually conform in dip and strike with the Bethel schist with which the chlorites are intimately associated. They may also appear in the same manner in the members of the Missisquoi group, but they occur in the latter formations with far less frequency. The majority of them therefore appear in the Bethel schist and are regarded as of sedimentary origin, but where they cross the sedimentaries at angles varying from zero to nearly ninety degrees they must be regarded as of igneous origin.

The chlorites are fine grained, green, schistose and highly metamorphic rocks. The mineral chlorite, or some related species of the chlorite group is their determinant species. Epidote and magnetite are invariably present. Quartz grains and plagioclase feldspars are usually sparingly present, but stringers of granular quartz may appear.

CAVENDISH SCHIST

The introduction of the term Cavendish schist is new in Vermont Geological literature. The term is necessary because the characteristics of the terrane will not permit it to be included in any group hitherto named. The name Cavendish is selected because this terrane is essentially the one in which the post-glacial gorge which is so widely known as Cavendish Gorge has been cut.

The essential mineral composition of this schist is quartz and biotite. It is often hornblendic and the hornblende sometimes replaces nearly all of the biotite. Among the accessory minerals epidote is very abundant, a plagioclase feldspar is universally present in small amounts, garnet, tourmaline, apatite grains, chlorite, pyrite and magnetite are common. It is dark gray in color. In stratigraphic position this schist underlies all members of the Missisquoi group. The actual contact of this schist with the Gassetts schist, Missisquoi, can be seen in the road cut a few rods north of Gassetts station. Arguments are not conclusive that it either underlies or overlies the Bethel schist, which is regarded as the oldest of the Upper Cambrian formations in eastern Vermont.

FIGURE 23.—Cavendish schist, showing westerly dip, railroad cut, Cavendish, Vt.

The conclusion, however, of the author of this report is that the Cavendish schist is the time equivalent of the Bethel schist. It is definitely proved that between these two schists and overlying them the Gassetts schist, sericite schist and sericitic quartzites occur.

The strike of this schist varies from north and south to north thirty degrees east. The dip on the east is at a high angle to the east and on the west at a high angle to the west. Near the central line of the formation as on Hawks Mountain in Cavendish and Baltimore the dip is nearly horizontal. This terrane, therefore, carries a major anticline. (See Figure 23.)

In its geographic distribution it extends north a short distance from Cavendish Gorge, southward and eastward over Hawks Mountain in Cavendish, Baltimore and Weathersfield and southward in Chester and Springfield. How far to the east it extends in Weathersfield and Springfield is only a matter of conjecture but it is obvious that this is the prevailing terrane along the western border of these last two townships where it is not replaced by the Reading gneiss hereinafter described.

When the schistosity was introduced into the pre-Ordovician and Ordovician terranes in eastern Vermont has been a matter of considerable interest and speculation. This formation gives us some evidence of the time of the last intense folding. An interesting boulder of the Cavendish schist occurs in an open pasture one and one-half miles north of North Springfield and about one-fourth mile north of the Weathersfield-Springfield town line. This boulder is ninety feet in circumference, eleven feet in height with length and breadth nearly equal. This boulder is cut by several pegmatite dikes which are broken and the flowage goes around the pegmatite blocks. The central pegmatite dike is broken twenty-seven times as recorded in going around the boulder and in some instances the distance of separation of two pegmatite blocks is fifteen inches. The flowage or schistosity planes passes between these pegmatite blocks as shown in Figure 24.

It is generally accepted that the granites of eastern Vermont were introduced during Devonian times. These granites are often cut by pegmatite dikes. Such dikes are particularly common in the area covered by this report. If these pegmatite dikes are late Devonian, for they could not be introduced until the granites had cooled sufficiently to fracture, or post-Devonian in age, then this intense stretching and fracturing of the pegmatite and the introduction of the schistosity may have occurred during the uplift at the close of the Carboniferous. This, however, is not intended to imply that no schistosity was introduced prior to that date.

MISSISQUOI GROUP

The Missisquoi Group of terranes comprises sericite schists, sericitic quartzites and a coarse textured, highly garnetiferous muscovite schist, as its chief constituents with minor beds of chlorite schist, hornblende schist and gneiss that may not be of sedimentary origin in all instances. This group of terranes has been followed southward from the international boundary on the north into Windham county, a distance of nearly one hundred and forty miles. The mineralogical content of the sericite schists and quartzites was fairly constant as far south as Bethel where biotite began to appear replacing a part of the fine grained silvery white sericite. In Bethel the biotite was regarded as only a minor accessory constituent. Southward from Bethel along the line of the strike the biotite content increases so rapidly that the rock in certain outcrops is best listed as a biotitic sericite schist. Further to the south the biotite is in excess of the sericite and the rock is listed as a sericitic biotite schist. Plagioclase feldspars are more abundant in Cavendish and Chester than in the more northern townships save for a single locality in Roxbury.

FIGURE 24.—Stretched pegmatite dike in a boulder of Cavendish schist, Weathersfield, Vt.

The silvery white, highly garnetiferous muscovite schist was discovered for the first time in Reading, 1926, and supposed then to be purely local but its occurrence in Reading, Cavendish and Chester leads to the introduction of a new member into the Missisquoi Group. This new terrane has been named the Gassetts schist from its occurrence in a large exposure, easy of access in the road cut a few rods north of Gassetts Railroad Station.

GASSETTS SCHIST

The Gassetts schist is a silvery white, highly garnetiferous muscovite schist. The texture is scaly, or the muscovite is arranged in parallel plates and is by far the most abundant constituent. It is not the fine grained silvery white sericite of the sericite schist. The quartz grains are somewhat angular. The garnets vary in size up to an inch or more in diameter. In form they are rhombic dodeckahedrons and probably the common almandite. Well defined tourmaline crystals are abundant, staurolites are also abundant. The magnetite is drawn out into more or less parallel lines. There are a few plates of biotite and a few grains of apatite. There is also present an unidentified prismatic mineral.

The rock represents a highly metamorphosed sediment that in certain outcrops has been affected by intrusives bearing boron and fluorine. In its stratigraphic position it underlies the typical sericite schists and quartzites and overlies the Bethel and Cavendish schists. If the Bethel and Cavendish schists represent the lower part of the Upper Cambrian and the sericite schists and sericitic quartzites the upper part of the Upper Cambrian then the Gassetts schist should fall in time relation in about the middle of the Upper Cambrian.

This terrane appears in a valley in the southeastern corner of Reading, in the eastern part of Cavendish about one mile west of the Cavendish-Weathersfield town line, in Baltimore on Hawkes Mountain, at Gassetts in the northern part of Chester and also on the hills in the extreme southern part of Chester. Its strike varies from north and south to north forty-five degrees east in the more northern outcrops. Its dip is everywhere to the west with an angle of seventy to seventy-five degrees. As already noted it is underlaid by the Cavendish schist.

SERICITE SCHIST

The sericite schists flank the Bethel schist on the east in Reading, Cavendish, Chester and Windham and are therefore younger than the Bethel schist. They also flank the Gassetts schist on the west and are therefore younger than the Gassetts schist. However, it is possible that the Gassetts schist has been subjected to greater metamorphism and greater effect of deep-seated intrusives than the typical sericite schist that has been so distinct in its characteristics from the international boundary on the north, southward to Chester. Where the silvery white, fine, scaly sericite predominates over the fine quartz grains the rock is listed as a sericite schist but where the well rounded quartz grains are far in excess of the sericite the rock is listed as a sericitic quartzite.

In Reading the sericite schists are largely confined to the extreme western part of the township, and even here much of the rock may be a granite gneiss. It is possible that a part of the hills west of Felchville in the southeastern part of Reading should also be listed as sericite schist.

In Cavendish the sericite schist is prominent in the western part of the township. It lies to the west of the belt of phyllite and limestone of Ordovician age that extends in a north and south direction across the entire township. It appears again in the central part of the township in a north and south terrane where it carries extensive areas of a granite gneiss. In Chester it comprises a large part of the rock in the western half of the township but it was nowhere found east of the Rutland railroad. A large part of the area in which this terrane falls is now occupied by a granite gneiss. The formation extends southward into Windham County.

The strike of the sericite schist ranges from due north and south to north forty degrees east. In the western portion of the terrane the dip is to the east and in the more eastern outcrops the dip is to the west. The dip is from seventy to seventy-five degrees east on the west side and seventy to seventy-five degrees west on the east side. Between these limits there are extremely high dips both to the east and west with numerous minor anticlines and synclines in its structure. This close folding is very pronounced on Butternut Hill in the central part of the township of Chester. On the high altitudes in the southern part of Chester between the Chester-Andover main road and the Poplar Dungeon road in a section twelve feet in length and six feet in height, there are three sharp anticlines and three sharp synclines. (See Figure 25.)

In structure the sericite schists are finely laminated, schistose and granular. In texture they are fine to medium grained. In color they range from a silvery white to a slightly greenish tint. The greenish color is due in some instances to the chloritization of biotite, and in others to hornblende. In both cases, the greenish tint is intensified by grains of epidote which results from the interaction of the feldspars and the ferromagnesian minerals.

The only essential minerals in the sericite schists are muscovite, *var.* sericite, and quartz. The normal accessory minerals are biotite, albite, magnetite, apatite, and pyrite. In some instances the rock is garnetiferous.

QUARTZITE

The quartzites as they appear in Reading, Cavendish and Chester are always somewhat sericitic and graduate insensibly into the sericite schist. In fact the quartzite is only a very quartzose phase of the sericite schist. In some instances as in the high altitudes near the central part of Chester there is little else present than well rounded quartz grains. The beds are often thin with

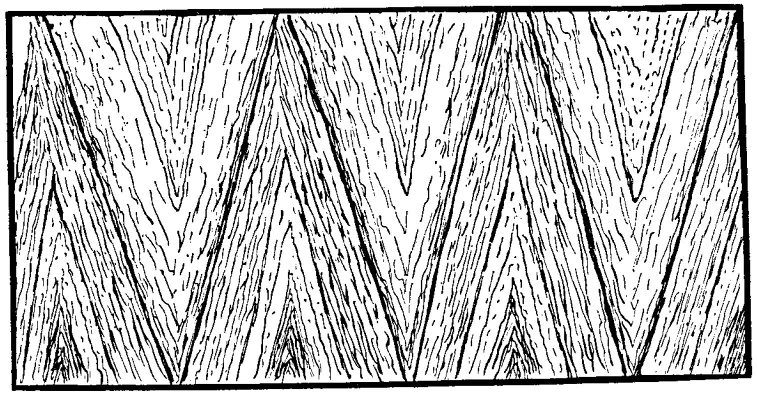

FIGURE 25.—Close folding in gneissoid rock, southern Chester, Vt.

dip and strike conforming to those of the sericite schists. No attempt has been made to differentiate these beds in mapping for the time element has been insufficient for such detailed work. They are far less abundant in Reading, Cavendish, and Chester than in the more northern townships unless the widely distributed gneiss in the area covered by this report is in reality a feldspathic quartzite. Further detailed petrographic study is here needed. While ample samples have been collected for this study it is doubtful if the full petrographic results can be available at the time this report has to go to press.

CHLORITE SCHISTS

There are thin beds of chlorite schist in the Missisquoi Group that conform in dip and strike to the dip and strike of the enclosing sericite schists and sericitic quartzites. They are regarded as of sedimentary origin for the following reasons:

(1) The narrowness of the beds.

(2) Their conformity in dip and strike to beds of unquestioned sedimentary origin.

(3) The presence of an appreciable amount of quartz in some slides.

(4) The absence of any alteration by igneous intrusions in the walls of the enclosing sediments. If the above interpretation is correct then the age of these chlorite schists would be the same as that of the enclosing sericite schists and quartzites. Upper Cambrian. The chlorite schists that cut across the strike of the sericites are of igneous origin.

HORNBLENDE SCHISTS

There are lenticular beds of hornblende schist in Reading, Cavendish, Baltimore and Chester that may represent hornblendized sediments. They constitute a very minor part of the Missisquoi Group. If they were of sedimentary origin then their age must be Upper Cambrian, the same as the enclosing sediments.

The arguments in favor of a sedimentary origin may be listed as follows:

(1) The gradation from outcrops particularly rich in hornblende to sericite schists and quartzites in which hornblende crystals are only sparingly present.

(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 of the rock.

(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 arguments in favor of an igneous origin of many of the lenticular outcrops of the bornblende schists may be listed as follows:

(1) The lenticular character of the hornblende outcrops.

(2) The massiveness of the rock in several of its outcrops.

(3) The definite rectangular jointing into small blocks from an inch to six inches in length as if by contraction during rapid cooling.

(4) The presence of crystals of tourmaline which, however, are not found in all the outcrops.

(5) Apparent apophyses of a basic igneous rock in the sericite schists.

(6) A border zone of either quartz, or pegmatite, sometimes tourmalinized that bears a striking contrast in color and mineral composition with the enclosing sediments.

(7) The abundance of plagioclase feldspars in certain layers so that the rock now appears as a hornblende gneiss, for rocks highly feldspathic are more apt to be of igneous origin than of sedimentary origin.

(8) The wedging apart of beds of unquestioned sedimentary origin so that the same narrow beds pass around the hornblendic rocks, a condition that could not obtain in sedimentation. This condition is well illustrated on the south slope of Bailey Hill in Cavendish just north of the Cavendish-Chester town line.

ORDOVICIAN

The area covered by the Ordovician terranes in this report is far less extensive than that covered in the report on Barnard, Pomfret and Woodstock. The breadth of these formations is the widest in the north in Reading and disappears entirely in the northern part of Chester. The extreme western part of Reading is probably Cambrian and the extreme southeastern part is also pre-Ordovician probably Cambrian, the most of the township is therefore Ordovician. The extreme western part of Cavendish is Cambrian which is flanked on the east by a V-shaped area of Ordovician which is the widest in the northern part of Cavendish and narrows rapidly toward the south. In Baltimore the Ordovician terranes do not appear. In Chester they are confined to the northwestern corner of the township, north of Smokeshire. They were not found in the bed of the brook flowing easterly through Smokeshire Valley, nor were they definitely observed on the high altitudes to the south of the Valley. The conclusion, therefore, is that the Ordovician here has been entirely removed by erosion, and will not appear again southward in Vermont on the line of this meridian. The occurrence of a tongue of pre-Ordovician terranes to the east of this western belt of Ordovician can be explained by a pitching fold in the Cambrian. Stratigraphically the Ordovician terranes lie in a trough in the pre-Ordovician formations. The earlier rocks on the west dip at a high angle to the east and on the east they dip at a high angle to the west. This condition has been observed in five cross sections traversing Cavendish and Chester.

Between the easternmost outcrops of the pre-Ordovician in Cavendish, Baltimore and Chester and the Connecticut River there is a continuous belt of Ordovician rocks that lie unconformably upon the pre-Ordovician terranes. They continue southward into Massachusetts. The eastern half of the Brattleboro Quadrangle falls entirely in the Ordovician. The dip on the western margin is to the east. These terranes are largely phyllite with some slate as in Dummerston and Guilford and beds of limestone or quartzose marble as in Putney and Guilford. Since the township of Brattleboro is practically all covered with a fine grained, graphitic phyllite schist this terrane is named the Brattleboro phyllite. This name was first applied to these phyllites by the author of this report at the time the extensive excavations were made in the phyllite for the new railroad station at Brattleboro in 1915. The term Brattleboro phyllite is applied to all the phyllites that lie between the eastern margin of the tongue of Cambrian extending northward into Cavendish and Chester and the Connecticut River and extending southward to the Massachusetts line. These phyllites are the youngest formations in southeastern Vermont.

IRASBURG CONGLOMERATE

The Irasburg conglomerate with its striking characteristics as seen in the section from Northfield to Coventry does not appear as such in Reading, Cavendish and Chester. However, the line of break between the Cambrian and Ordovician that was so pronounced in the Ottauquechee Valley near the Bridgewater-Woodstock town line is continued southward to Smokeshire in the northwestern corner of Chester.

WAITS RIVER LIMESTONE

The Waits River limestone with its associated beds of marble traverses Reading in a broad belt. In fact nearly three-fourths of the township of Reading is covered with this limestone series. The belt is the widest in the northern part of the township. It extends westward from the Reading-West Windsor town line to about two miles west of Reading Center. A little to the southwest of Reading Center the limestone is replaced by phyllite. In the southeastern part of the township the limestone is replaced by a quartzite or gneiss. This is especially true of the region around Felchville. West of Reading Center and South Reading the limestone series extends across the entire township. It forms a broad belt in Woodstock on the north and a very narrow belt in Cavendish on the south. In the extreme southern part of Reading only a few rods east of the first road to the right from the north-south road in Cavendish and Reading, there is in an open pasture, a glacial boulder of Waits River limestone, well rounded and weighing about 75 tons that rests upon an outcrop of the Waits River limestone. This is the first instance observed of such a gigantic boulder of limestone resting upon limestone.

In Cavendish there is but one belt of the Waits River limestone. This belt extends across the entire township through Proctorsville in a direction of north ten to twenty degrees east. The belt is narrow and associated with much phyllite.

In Chester to the north of Smokeshire in the northwestern part of the township there are a few thin beds of limestone interstratified with the phyllite. South of the Smokeshire Valley the Ordovician limestones do not seem to appear. Ordovician limestones do not occur in Baltimore.

The general strike of the limestones and marble beds in the townships covered by this report varies from north and south to north twenty degrees east. Local beds were found in Reading with strike of north thirty degrees east. The dips are at high angles both to the east and the west. In general the dips on the west side are eighty to eighty-five degrees east but on Bailey Hill in Reading a dip of eighty-five degrees west was observed.

Some of the beds in Reading are sufficiently massive and recrystallized to receive a handsome polish and are therefore a marble. In the neighborhood of Baileys Mills in Reading there is an outcrop of the limestone that is completely recrystallized and under the petrographic microscopic shows beautifully the cleavage lines of the calcite crystals.

The only essential minerals in the Waits River limestones and marbles are calcite and quartz. The quartz grains are often well rounded and water-worn. The accessory minerals are a few scales of muscovite, occasionally a plate of biotite, microlites of pyrite, or a carbonate containing a little iron. Uncombined carbon provides the pigment. The rock is best classified as a quartzose marble. It is in reality a marble and a quartzite combined in one dual rock.

MEMPHREMAGOG GROUP

The Memphremagog Group consists of slates and phyllites. In the northern half of the state the slates have appeared as a continuous formation. The phyllites have been more or less broken in their continuity by the Waits River limestone. To the southwest of Reading Center such a bed of phyllite is completely surrounded by limestone.

SLATE

The Memphremagog slate does not occur in Reading, Cavendish and Chester. This terrane which was so persistent in the northern part of the state as in Northfield, Montpelier, Coventry and Newport has lost its fissility, so that it is no longer a commercial possibility as a roofing material. The position normally occupied by the slate belt is now represented by the more highly metamorphosed, fine grained, graphitic, phyllite schist.

RANDOLPH PHYLLITE

The Randolph phyllite which is a member of the Memphremagog Group forms a continuous terrane across the western part of Reading and Cavendish. It is a comparatively narrow belt flanked on the east by the Ordovician Waits River limestone and on the west by the Cambrian sericite schist and Cambrian gneiss. It extends southward for only a short distance into Chester in the northwestern part of Chester to the north of Smokeshire Valley and was not found on the high altitude to the south of the valley. It appears that this marks the southern limit of the Ordovician in Vermont on the west side of the broad belt of pre-Ordovician rocks, probably Cambrian, in Cavendish and Chester. It must be remembered that on the east side of the same pre-Ordovician terranes the Ordovician phyllites, Brattleboro phyllite, extends southward into Massachusetts. To the southwest of Reading Center there is a lenticular area of phyllite that is completely encircled by Waits River limestone. In Baltimore the Randolph phyllite does not occur.

The general strike of the phyllite varies from north and south to north twenty degrees east but local strikes north thirty degrees east were recorded. The phyllites are closely folded and dip at high angles both to the east and west. This condition can be observed on Bailey Hill in the southwestern part of Cavendish where dips of eighty-five degrees both east and west were recorded. It must be expected that beds of phyllite are entirely absent in areas mapped in as limestone, or that beds of limestone are entirely absent from areas mapped in as phyllite. The areas are mapped according to which type of rock seems to predominate. The limestones and the phyllites are so interstratified at times that in a distance one hundred feet across the strike fifteen or twenty different beds of limestone and as many different beds of phyllite can be observed. In some instances as on Bailey Hill the limestone layers so intimately interstratified with the phyllite vary in width from two inches to one foot.

BRATTLEBORO PHYLLITE

As heretofore noted the term Brattleboro phyllite is applied to all the phyllites that flank the Cavendish schist and the Reading gneiss on the east of Reading, Cavendish, Baltimore and Chester. Its home is in Springfield, Rockingham, Putney, Brattleboro, Guilford, Vernon and continues southward into Massachusetts. The Waits River limestone is more or less interstratified with the Brattleboro phyllite as in the northern part of Putney but these beds are less extensive in the Brattleboro phyllite than they are in the Randolph phyllite in the central and northern portion of the State. The name Brattleboro phyllite was first applied by the author of this report to the phyllites of the Connecticut Valley in the year that so much blasting was done and so much phyllite removed in Brattleboro for the new railroad station at Brattleboro in 1915.

ACID INTRUSIVES

The acid intrusives in Reading, Cavendish, Baltimore and Chester are widely distributed. They range in mineralogical composition from aplites to syenites. The last named rock might be listed as intermediate.

GRANITE

There is a small granite area a little east of the village of Cavendish. This granite is of medium gray color and of fine to medium texture. The feldspars are somewhat larger than the quartz grains. The biotite is well crystallized and affords an excellent illustration of the formation of epidote by the interaction of the feldspars and the ferromagnesium minerals. It also gives an unquestioned illustration of the transition of biotite to chlorite.

The essential mineral composition is quartz, orthoclase, albite-oligoclase and biotite. The accessory minerals are a few plates of muscovite, a little chlorite, abundant epidote, a few crystals of apatite and a few minute zircon crystals.

There is quite a large granite area in southeastern Cavendish, western Baltimore and northern Chester. The various outcrops in these three townships appear to be continuous. It has been quarried to some extent about one mile northeast of Gassetts railroad station.

The largest granite outcrop in the area covered by this report is located about two miles northeast of the village of Chester. It is owned and operated by the Gosselin Granite Company of Springfield, Vermont. This granite is of medium gray color and of even granular texture. It carries both muscovite and biotite. Its mineral composition in descending order is quartz, albite to albite-oligoclase, microcline, orthoclase, muscovite, biotite, epidote, apatite, zircon and magnetite.(See Figure 26.)

APLITE

Fine grained aplite dikes are not uncommon in Reading, Cavendish, Baltimore and Chester. They range in width from a fraction of an inch up to several feet. Their essential minerals are quartz, orthoclase or microcline, albite to albite-oligoclase and a very little muscovite in minute scales or plates. Biotite plates have been observed, also small apatite crystals. One of these aplites can be seen in the underpass of the railroad about one mile south of Cavendish.

FIGURE 26.—Quarry of the Gosselin Granite Company, Chester, Vt.

PEGMATITE

Pegmatites are very widely distributed in Reading, Cavendish, Baltimore and Chester. They are found on nearly all the higher altitudes cutting the granites and the granite gneisses. In Cavendish on the north side of what is known as the Crown Point Road, built by General Amherst in 1760 and reworked by the Cavendish Chapter of the D. A. R. 1915, there is a pegmatite dike that cuts the granite gneiss. The gneiss is the medium gray color. The pegmatite is of light gray color. This dike shows no schistosity whatever and the contact wall is clearly marked. The gneiss is of medium, granular texture and the dike is of course texture.

The mineral composition of the pegmatite in descending order is quartz, orthoclase or microcline, albite to albite-oligoclase, muscovite, biotite, epidote, apatite, magnetite.

The best pegmatites in Baltimore occur on the open hill at an altitude of 1,205 feet about one mile south of the school house. There is a broad belt of this pegmatite with strike nearly east and west that might be listed as a coarse textured granite. There is a

second belt, somewhat narrower than the first, with strike nearly north and south that is a true pegmatite. (See Figure 27.)

The largest pegmatite deposit in Chester is on the H. H. Lewis farm on what is known as the Trebo road one and one-half miles northeast of the railroad station at Chester. This pegmatite has been quarried for its potash content by E. J. Davis of Chester.

FIGURE 27.—Pegmatite outcrop, Baltimore, Vt.

According to an expert report on this property the length of the pegmatite outcrop is 1,500 feet and the breadth is 400 feet. The actual depth is unknown. The strike is northeast and southwest. An analysis of a sample of this pegmatite made in the laboratories of the New England Laboratories, Inc., Springfield, Mass., gave the following:

	Percent
SiO_2	65.91
Al_2O_3	19.13
Fe_2O_3	.05
MnO	.04
CaO	.15
MgO	.20
K_2O	12.45
Na_2O	2.12
	100.05

Good pegmatite occurs on the Owen Johnson farm one and one-half miles east of the village of Chester. The outcrop extends for several rods in an east and west direction and is at least 15 feet in width. Excavation work in the repair of the Chester-Springfield road shows this pegmatite in a narrower vein. The two outcrops are doubtless connected. The feldspar is of pink or flesh color and looks like very high grade orthoclase. Microscopic slides reveal the fact that the feldspar is essentially microcline instead of orthoclase but this does not lower the potash content and therefore does not diminish its commercial value.

Another pegmatite vein occurs on the farm of Gladys Stoodley two miles east of Chester. This dike is 6 feet in width. Pegmatites also occur on Mt. Flamstead just east of the village of Chester. They occur in Grafton on the farm of A. Johnson near the Chester-Grafton town line about five miles from the village of Chester. A perthitic pegmatite occurs on the farm of Wilbur W. Stevens which is the last farm in Chester on Soapstone Hill. This pegmatite appears low in its mica content. There is a well defined pegmatite dike just north of the concrete bridge over the railroad at Gassetts in Chester.

SYENITE

Syenite occurs on the south slope of the hill about two miles southeast of Felchville but in the township of West Windsor. The rock is of medium gray color and of medium to coarse texture and massive. The joint planes are well spaced so that commercial blocks can be easily obtained.

In mineral composition plagioclase feldspars that show polysynthetic twinning are most abundant, a little orthoclase, hornblende, augite, sporadic quartz, epidote and apparently the cerium epidote, orthite, ilmenite altering to leucoxene. Apatite and zircon crystals are fairly abundant.

TRACHY-DACITE

This is the first recorded occurrence of this rock in Vermont and so far as known to the author it has not been reported to occur elsewhere. Its occurrence in Reading is on the east side of the Reading-Woodstock road just north of the village of Felchville. The dike can be followed for several hundred feet over the hill to the east. Its width is approximately twenty-five feet. The rock is light gray in color or yellowish, probably due to the oxidation of an iron content. It is very fine grained, dense or felsitic. In the field it might well be listed as a felsite. It cuts the granite gneiss.

The texture of the rock is trachytic. There is no apparent parallelism in the arrangement of any constituent. Most of the mineral grains are small and uniformly arranged throughout the slide. In composition the plagioclase feldspars of the more acid varieties are the most prominent components. Orthoclase, quartz, hornblende and augite constitute the remainder of the essential minerals. The minor accessories are apatite, zircon and magnetite. The last named mineral is fairly abundant.

READING GNEISS

The term Reading gneiss is new in Vermont geology. Its introduction is demanded by the discovery of large areas of rocks that will not fall within the ranges given to any other formation or group of terranes. The reason for selecting the name Reading is that the outcrops of the gneiss occupy the whole of the southern part of Reading. The rock cut just north of the village of Felchville is in this gneiss.

The term Reading gneiss as here used embraces a widely distributed group of rocks in Reading, Cavendish, Baltimore and Chester whose essential mineral composition is quartz, orthoclase or microcline, or both. Albite to albite- oligoclase and muscovite or biotite, or both. There is present as accessory minerals epidote, sometimes chlorite from the alteration of biotite, small apatite and zircon crystals. Hornblende is sometimes present as if replacing biotite.

The Reading gneiss is essentially an ortho-gneiss that is, one derived from the shearing or metamorphism of a granite. The proof of this lies in the fact that the petrographic study of a large number of microscopic slides reveals an abundance of microcline in nearly every slide. It may in part be a para-gneiss, that is one derived from the metamorphism of highly feldspathic sediments. This would not account for the abundance of microcline. It may in part be an injection gneiss or migmatite. In certain sections there are zones of distinct granite gneiss passing into zones that carry alternating granite gneiss and dark bands that suggest half-incorporated sediments. This condition may be followed by veinlets of granite gneiss in beds that suggest a sedimentary origin. The microscopic slides from some of these beds showed the presence of microcline.

It seems better to the author of this report to regard the Reading gneiss in all its variations as originally a great granite batholith essentially a biotite granite which has become subsequently sheared into a granite gneiss rather than to believe that the foundation of this formation was a quartzite which was converted into a gneiss by the introduction of feldspars, albite to

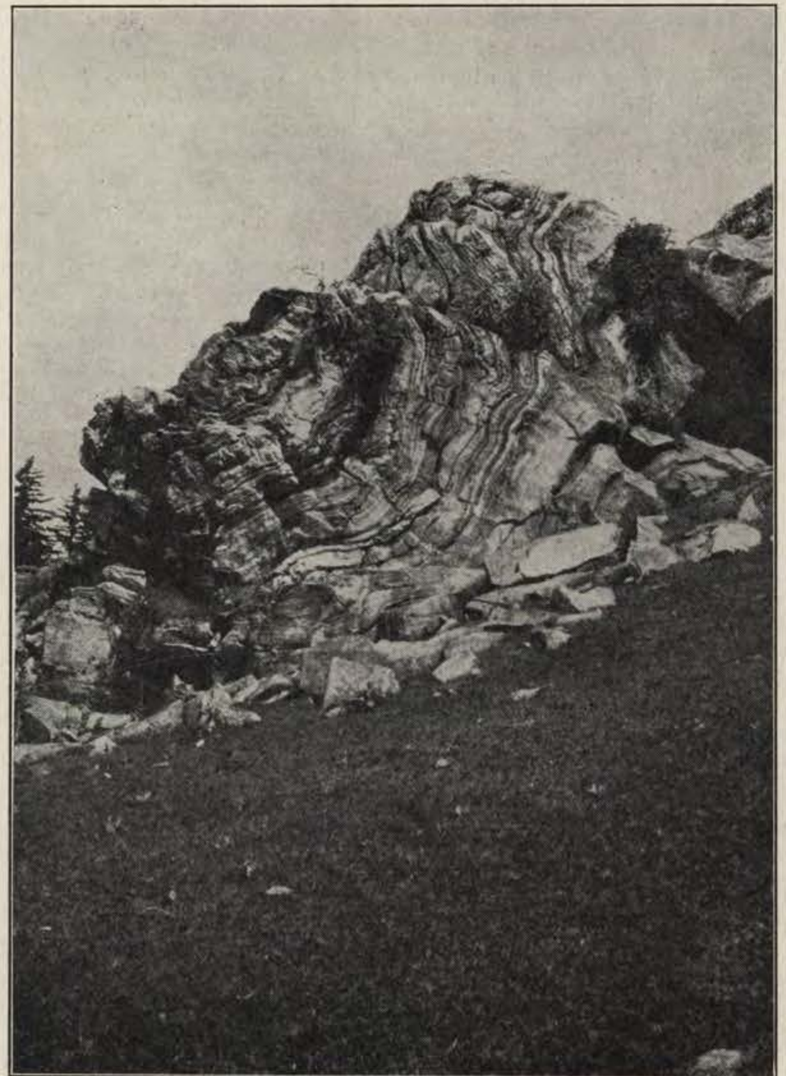

FIGURE 28.—Reading gneiss showing westerly dip, Felchville, Vt.

albite-oligoclase and orthoclase and that the orthoclase was in part subsequently converted into microcline. The conversion of orthoclase into microcline could not have been complete for both orthoclase and microcline are present in some of the slides.

The delineation of this formation upon the areal map is attended with great difficulty and inaccuracy. It may include purely sedimentary beds, but where the gneissic character predominates the area is mapped as gneiss. In its areal distribution it will appear in the southeastern part of Reading, the southwestern part of West Windsor and may extend north into Hartland, in the eastern half of Cavendish, the extreme western part of Weathersfield, in Baltimore, in nearly all of the eastern half of Chester and in the southwestern corner of Springfield.

The strike of the Reading gneiss varies from north and south to east and west but the average strike is approximately north thirty degrees east. The dips of the beds in general are easterly on the east followed by the crest of an anticline. Then westerly dip and again an easterly dip followed by a westerly dip. The dips are almost exclusively at high angles as shown in Figure 28, which represents the eastern side of a syncline for on the high altitudes to the west of the Reading-Woodstock road the curves are just as marked to the east. (See Figure 28.) In the southern part of Chester between the Chester-Andover road and the Poplar Dungeon road one exposed section 12 feet in length and 6 feet in height gave 3 sharp anticlines and 3 equally sharp synclines. The rock exposed in the washout in Cavendish on November 4 and 5, 1927, is the Reading gneiss. (See Figure 21.)

BASIC INTRUSIVES

Basic intrusives are abundant and widely distributed in Reading, Cavendish, Baltimore and Chester. They have invaded both the Cambrian and the Ordovician terranes, but they are more abundant in the former than in the latter formations. In eastern Vermont the converse holds true of the acid intrusives. In the more northern areas of the state the commercial granites are far more abundant in the limestones and their associated phyllites than in the Bethel schists, sericite schists and sericitic quartzites. The basic intrusives in the area involved in this report consist of diorites, diorite gneisses, diabases, pyroxenites and peridotites.

DIORITE AND DIORITE GNEISS

The diorites are granitoid igneous rocks whose chief feldspar is usually the plagioclase feldspar andesine, but in eastern Vermont this feldspar is often richer in sodium than andesine through albitization, and whose chief ferromagnesian mineral is hornblende, but augite may be present in an appreciable amount and the rock becomes an augite diorite. An appreciable amount of quartz gives rise to the term quartz diorite. The presence of biotite in sufficient amount gives rise to the term mica diorite. The shearing of the diorite so that the ferromagnesian minerals are in parallel lines gives rise to the term diorite gneiss. Chlorite, epidote, magnetite, or ilmenite, and apatite, are the common accessories.

An interesting outcrop of diorite gneiss occurs about one mile north of Proctorsville on the twenty-mile stream in Cavendish. The length of these hornblende outcrops exceeds one mile and the breadth is several hundred feet. This diorite gneiss is dark gray in color and of fine to medium texture. In the field the blocks are fairly tough due to the excess of hornblende in the darker phases of the diorite gneiss. The hornblende crystals sometimes interlock each other.

This diorite gneiss is from fine to medium in texture and granular. The crystals of hornblende are medium to coarse and the most of them are drawn out into parallel lines. Under transmitted light, the hornblende is greenish to greenish blue. The quartz and feldspars are very fine grained, calcite is fairly abundant and derived from the alteration of the soda-lime feldspars. There is a little biotite present. Numerous tourmaline crystals suggests igneous activity. The original rock may have been a diorite. There are phases of this outcrop that are richer and poorer in hornblende than the phase here described.

On Bailey Hill in the southwestern corner of Cavendish just north of Smokeshire Valley there is a very interesting outcrop of hornblende schist or gneiss that is unquestionably of igneous origin. It cuts the Ordovician limestones and phyllites in a pronounced V-shaped manner without any apparent alteration of either the limestones or the phyllites. In this rock there is much epidote, pyrite and magnetite. Pyrite in two long vein-like masses shows hematitization on either border. The epidote is often in parallel alignment with the hornblende.

There is an interesting outcrop of hornblende schist or hornblende gneiss in the south slope of the rock cut in the Gulf road from Proctorsville to Chester but in Cavendish. The rock varies in color from a light gray to dark gray according to the amount of hornblende that is present, and from fine to coarse texture according to the size of the hornblende crystals. The finer phases would be listed in the field as a hornblende schist while the coarser phases might well be listed as a gneiss. This rock may have been a sediment in which the hornblende has been developed through the introduction of solutions rich in calcium and magnesium.

Diorites occur abundantly on the east side of the road from Gassetts to Chester and about one mile south of Gassetts Station. The outcrops extend some distance back on the hills to the east. In some instances the rock is extremely tough and shows little if any sign of parallelism in the ferromagnesian minerals. In other instances the parallelism is so apparent that the rock is best listed as a diorite gneiss. Diorite gneisses occur in the eastern part of Chester near the Springfield town line and also in the southeastern corner of Chester about one mile north of Bartonsville. In the latter locality the original diorite occurs as a dike cutting the Cambrian terranes. Its strike is north twenty degrees east and its width is ten feet. It is now folded into a very sharp anticline. Many other localities might be listed of these hornblende rocks but space will not permit listing them all.

DIABASE

Dikes of diabase are fairly common in Reading, Cavendish, Baltimore and Chester. They cut both Cambrian and Ordovician terranes. As a rule these dikes are high in specific gravity, dark in color, massive, fine grained and ophitic. In some instances they show spheroidal weathering, with spheroids varying in diameter from the fraction of an inch up to two feet. As a rule they are narrow, sometimes even less than a foot in diameter and in some instances they reach fifty feet in thickness and are very massive. The pyroxene, augite, and the plagioclase feldspar, labradorite, are the only essential constituents. Magnetite is invariably present. Hornblende is frequently present perhaps derived from augite rather than original mineral. Chlorite is present in some dikes and is derived from hornblende. Epidote is common and calcite frequently appears derived from the alteration of the soda lime feldspars.

An interesting dike of amygdaloidal diabase occurs on the west slope of the hill north of the Felchville-South Reading road. This rock is exceedingly tough and breaks with a deep conchoidal fracture. The amygdaloidal cavities are now filled with secondary calcite.

In the northwest corner of Cavendish in the open pasture of J. O. Cady a dike of diabase cuts the Ordovician slates and phyllites. Its strike is north seventy degrees west. Its dip is nearly vertical. Its width approximately five feet.

In Reading some two miles west of the Brown school house, Camp Balsam, there is a diabase dike about two feet in width with strike north ten degrees east.

A diabase dike with zenoliths of syenite occurs in the southwest corner of West Windsor. It is on the west side of the cross road between the Felchville-Brownsville road and the Felchville-Perkinsville road. This dike is exposed for about ten rods along its strike east and west, and is forty feet in width.

The most interesting feature of this dike is that it gives us a little better idea of the time that so many diabase dikes were introduced into eastern Vermont. If the nordmarkite of Mt. Ascutney and the associated syenites were introduced as late as the Carboniferous then the diabase dikes may be Triassic for this dike carries distinct zenoliths of syenite.

Diabase dikes also occur in the southwest corner of Weathersfield, near the central part of Baltimore, in the eastern part of Chester and the western part of Springfield.

CHLORITE SCHISTS

Only those chlorite schists that have been derived from rocks of igneous origin belong here. They are intimately associated with the talc, soapstone and serpentine deposits, and perhaps the discussion belongs for this reason under the caption of pyroxenites and peridotites.

In the southeastern part of Chester, chlorite schists occur largely impregnated with pegmatite dikes. Lenses, stringers and apohyses of chlorite in the country rock, feldspathic quartzes or gneisses, show that the chlorites, or some related minerals of the chlorite group were developed from basic intrusives rather than from sediments rich in magnesium and iron.

In the eastern part of Baltimore and the southwestern corner of Weathersfield chlorite schists are well exposed. The chlorite is overlaid by a quartzite or gneiss that dips at a low angle to the east. A microscopic slide of this chlorite fails to show even a single sporadic grain of quartz. The rock is exceptionally pure chlorite.

PYROXENITES AND PERIDOTITES

Pyroxenites and peridotites altered to talc, steatite and serpentine, are abundant in the area covered by this report. They are more numerous in Chester than in Reading and Cavendish.

The Reading Talc Company operated a plant about 1910 at Hammondsville. An idle pebble mill still stands by the side of the Hammondsville-South Woodstock road. The main shaft stands about fifteen rods east of the mill. It is sixty-five to seventy feet in depth and 8 x 10 feet. A drift was extended fifteen feet to the east. The shaft is all in talc for the walls of the county rock were not encountered. A second opening was made some ten rods south of the main shaft. There is also a small opening a few rods west of the Hammondsville-South

Woodstock road and good talc also occurs on the Ethen Allen farm approximately one-half mile west of the pebble mill. The talc carries some dolomite in certain portions of the deposit and in others crystals of actinolite. By a sorting of the talc as it comes from the mine good commercial talc can be manufactured. The Vermont Talc Company with mill in Chester operates a talc mine which is situated in the northern part of Windham some ten miles southwest of Chester. The talc has been mined to a depth of one hundred sixty-five feet but the work of mining is now done by open cut. The width of the opening is one hundred fifty feet and the length three hundred feet. The east wall is chlorite and the west wall is serpentine. The walls dip away slightly from the talc on both sides. The talc is hauled to Chester by motor trucks. The supply of talc here appears inexhaustible. (See Figure 11.)

The American Soapstone Finish Company with mill in Chester mines talc from a deposit two and one-half miles west of the mill. The opening is one hundred twenty-five feet in depth, seventy-five feet in length and fifty feet in width. The talc is in part massive and in part foliated. Serpentine forms the north wall. There is some chlorite in the south wall. Beautiful actinotite is fairly abundant in lens-shaped masses. The mine was opened as a soapstone quarry about twenty-three years ago.

The Holden Quarry is situated some two miles south of the village of Chester. The soapstone is composed largely of radiating fibers which give the stone a markedly different appearance from the soapstone in Weathersfield.

Talc or soapstone deposits occur also in the southern part of Chester near the Grafton town line, along the Chester-Andover town line, south of Peaseville in Andover, on the hills south of the Smokeshire Valley in the northwestern part of Chester, along the Baltimore-Weathersfield town line. At the last named locality a large amount of soapstone has been quarried, but the quarries have been abandoned and the openings are now filled with water. The supply of soapstone was not exhausted.

In Ludlow about one mile east of the village and on the south side of the railroad a soapstone quarry was worked for many years. About two miles east of Ludlow and on the north side of the Ludlow-Proctorsville road, both talc and steatite have been mined. The Valentine mine is about one mile east of Ludlow and on the north side of the Ludlow-Proctorsville road. The main shaft is about seventy-five feet in depth. The strike of the vein is north twenty degrees east and the dip of the enclosing rocks is from eighty to eighty-five degrees west. The talc is excellent.

A large area of massive serpentine occurs on the north side of the road between Proctorsville and Ludlow and in both townships. The serpentine is massive. Microscopic slides show the rock to be well suited for decorative interior work. It is susceptible of a very high polish.

South of the Ludlow-Proctorsville road and in both the townships of Cavendish and Ludlow there is another large area of serpentine. The rock here is not as accessible for marketing as in the area listed above.

The origin of the talc and steatite deposits is through the hydrous metamorphism of pyroxenites. In some instances in Chester the argument is positive that some rock rich in ferromagnesian minerals was intruded into the gneiss which forms the country rock. The intrusive cuts across the gneiss and microscopic slides at the actual contact show little if any alteration of the gneiss while the intrusive is wholly altered to talc or steatite. Steatite or soapstone as it is known commercially, is simply impure, massive talc. The serpentines were derived from peridotite through hydrous metamorphism. Some of these peridotites were rich in olivine and microscopic slides not only show the outline of the original olivine crystals, but in some instances the crystals of olivine.

The age of the introduction of the pyroxenites and peridotites into Vermont terranes is regarded as Cambrian for they abound in terranes of Cambrian age but they nowhere cut the Ordovician formations. The line of contact between the Cambrian and Ordovician terranes has been followed by the author of this report the entire length of the state one hundred fifty miles, and the Ordovician rocks have been traversed across the strike more than one hundred times but no talc or serpentine deposit has yet been found in them.

PALEONTOLOGY

As yet no fossils have been found in the pre-Ordovician terranes on the eastern side of the Green Mountains. The relative age, therefore, of these formations has been determined by their stratigraphic position, continuity and lithological characteristics. The pre-Ordovician terranes as embraced in this report are unquestionably post-Algonkian for the base of the series is the Sherburne conglomerate which overlies the Algonkian. They occupy an inferior position to the Irasburg conglomerate which forms the base of the Ordovician in eastern Vermont. If the conjecture is correct that the Bethel schist carries a conglomerate bed in Windham then the inferior terranes between the Bethel schist and the Algonkian on the west would normally be classed as Lower Cambrian and the Bethel schist with its superior members would be classed as Upper Cambrian.

As to the age of the terranes listed for over thirty years as Ordovician in eastern Vermont, we now have conclusive proofs of age. The discovery of new beds of graptolites in Reading and Cavendish is significant. Since the western arm of the Ordovician terranes terminates in Chester, it seems advisable to list here both the geological formations in which these diagnastic features of age have been found and the townships in which they occur. Graptolites have been found in the matrix of the Irasburg conglomerate, in the different phases of the Waits River limestone, in the Northfield, Montpelier, Coventry and Newport phases of the Memphremagog slate and in the Randolph phyllite.

Since the graptolites were discovered in Coventry, June, 1927, in the northern part of the state it seems advisable to list the townships in a line southward across the state rather than in alphabetic order. The list, therefore, would be as follows: Newport, Derby, Salem, Coventry, Brownington, Irasburg, Barton, Albany, Glover, Craftsbury, Greensboro, Hardwick, Woodbury, Calais, East Montpelier, Montpelier, Berlin, Barre, Northfield, Williamstown, Roxbury, Brookfield, Braintree, Randolph, Bethel, Royalton, Barnard, Pomfret, Bridgewater, Reading, Cavendish.

It will be noticed that this line is continuous southward to the southermost township in which the Ordovician terranes occur in the central part of the state, and that the line in general is two townships in width. The graptolites are more numerous and better preserved in the townships that border the Cambrian terranes, than in the townships to the east, *i.e.*, they are far more abundant in Northfield than in Williamstown.

The identification of the graptolites has been made by Dr. Rudolf Ruedemann, State Paleontologist, Albany, New York. In a visit to my laboratory at Syracuse University last spring, Dr. Ruedemann identified the following species in the Vermont Ordovician, Beekmantown, Climacograptus pavus, Tetragraptus amii, Didymograptus subtenus, Dicranograptus ramosus, Phyllograptus ————, Dicellagraptus ————, and a crustacean Caryacaris. This crustacean was from Northfield. In the rocks which Dr. Ruedemann regarded as Normanskill, he identified Diplograptus englyphus and a Diplograptus species not determined.

Dr. Ruedemann in his letter of September 26, 1914, writes concerning specimens submitted from Graptolite Hill in Greensboro and the Valley Lake region in Woodbury. "These are quite certainly graptolites, probably branches of Dichrograptus and Didymograptus;" concerning samples from Craftsbury, he writes, "These suggest Phyllograptus and Diplograptus." Dr. Ruedemann had previously identified in material collected in Coventry and Brownington a Diplograptus and Climacograptus. In a letter of August 8, 1916, Dr. Ruedemann wrote concerning material collected near the Catholic Cemetery, Montpelier, "The most remarkable graptolite is undoubtedly a Tetragraptus amii———, and the broad blotches are quite probably Phyllograptus."

In 1918 concerning material sent from Berlin-Montpelier, he wrote, "The specimen you sent me is quite distinctly a small climacograptus. It shows still the characteristic outlines of the cells and the nemacaulus, also the original shape of the distal end."

Concerning material sent from the slate quarries in Northfield, Dr. Ruedemann in his letter of July 19, 1924, "Specimen No. 1 is the best of all. It shows in a certain light the characteritic structure of a Phyllograptus angustifolius. This indicates the Deepskill shale (Beekmantown)."

The argument, therefore, is conclusive that sedimentation began in eastern Vermont in Ordovician time as early as the Beekmantown, continued through the Normanskill, and probably ceased during the Trenton period. However, it is possible that some of the mica schists that overlie the Waits River limestone in the Connecticut Valley may be later than Trenton.

ECONOMICS

There are no known commercial metallic minerals in Reading, Cavendish, Baltimore and Chester, or in their immediate environs. However, the non-metallic minerals and building stone have played quite an important rôle in the history of these townships.

A few instances were found in Reading where the Waits River limestone, Ordovician, has been burned for lime and the massive blocks of quartzose marble used for constructional work. The most of the lime kilns burned the lens-shaped beds of marble, for microscopic slides show these beds to be well crystallized, that occur in the Cambrian. Such beds are generally limited in tonnage, the supply soon exhausted and the kiln abandoned. Many such abandoned kilns are found in Reading and Cavendish. One of these old kilns stands one-fourth mile south of Cavendish Gorge and about five rods west of the railroad.

Between the hill road from Felchville to Cavendish and Felchville to Perkinsville in an open pasture, a considerable amount of rock has been crushed for the manufacture of lime. At the south end of the hill a crushing plant is still active. There are three good openings for lime on this range of hills.

The Vermont Talc Company with mill in Chester and mine in the northern part of Windham manufactures a product so fine that more than 99 per cent. will pass through a 200 mesh sieve and 95 per cent. will pass through a 325 mesh seive. The finished talc finds use in the manufacture of paper, in the rubber industry, in insular wire and cable, in foundry facing and in several smaller industries.

The American Soapstone Finish Company with mill in Chester and mine two and one-half miles west of mill not only produces talc but also a slaty or micaceous product that is used largely for roofing purposes both as insulating material and as a filler.

The Holden Soapstone quarry in the southeastern part of Chester and the abandoned soapstone quarry in Weathersfield are possible future producers of soapstone. The mine of the Reading Talc Company at Hammondsville which has been idle for several years is capable of producing much commercial talc. There are many smaller deposits of talc that are well worthy of exploitation in these townships. Garnet for the manufacture of abrasives in several different varieties is a commercial possibility in Chester as at Gassetts where the silvery white Gassetts schist occurs in a road cut just north of Gassetts station, in the same formation in the southeastern part of Chester, in Cavendish on the north side of Black River, in Cavendish about two miles due north of the Black River deposit, in the southeastern part of Reading, and in a mica schist that may or may not be the same formation on the Andover-Chester town line.

Pegmatite dikes are a source of the potash feldspars orthoclase and microcline used as a fertilizer and in the manufacture of porcelain. Such feldspars are very common in what appear to be commercial outcrops in Chester as on the farm of H. H. Lewis on the Trebo road, on the Owen Johnson and Gladys Stoodley farms east of Chester, on the Wilbur Stevens farm in the extreme southern part of Chester and on the hill about one-half mile south of the school house in Baltimore.

Granite that can be used either for constructional or monumental work occurs in the quarries of the Gosselin Granite Company, Springfield, Vt. The quarries are located about two miles north of Chester and on the Trebo road. Quarries can also be opened in southern Cavendish, western Baltimore and northern Chester.

The Reading gneiss that is so widely distributed in Reading, Cavendish, Baltimore and Chester has been extensively used in the construction of private homes, churches, school houses and business blocks. Some of these structures erected nearly one hundred years ago are still in a good state of preservation.

The stone in the stone church in South Reading was quarried on the south side of Keyes Mountain which is situated between Baileys Mills and the South Reading road. The church was built about 1850. The house of F. H. Davis was built in 1857 of stone from the same quarries. It is understood that many of the stone houses in Reading were erected between 1845 and 1860 of stone from these same quarries.

In Cavendish and Proctorsville there are many stone structures built during that period between 1845 and 1860. The stone bank in Proctorsville was erected in 1846 with stone from the F. H. Wheeler farm in Cavendish.

The stone church in Chester was erected in 1845. The stone was quarried on Mt. Flamstead. There are many stone buildings in Chester that were erected during the period between 1845 and 1860 that are still in a fine state of preservation. They illustrate well the value of the Reading granite gneiss in constructional work.

THE CAMBRIAN PARADOXIDES BEDS OF NORTHWESTERN VERMONT

B. F. Howell

A small strip of shale, the St. Albans Formation, holding a *Paradoxides* fauna, probably of early Paradoxidian age, and apparently a remnant of a once larger body, most of which was removed by late Paradoxidian or early NeoCambrian erosion, extends some miles north and south of St. Albans, Franklin County, northwestern Vermont. This shale is described, its present known area and outcrops are shown, and its history is discussed. Its fauna will be described in a future paper.

The rocks of northwestern Vermont are of more than ordinary interest to geologists and paleontologists. Located, as they are, at the northern end of the long belt of fossiliferous Cambrian and Ordovician sedimentaries which stretches up through the Hudson and Champlain valleys, where that belt merges into the east-west trending belt of similar strata that underlies much of the St. Lawrence Valley, easy of access to both American and Canadian geologists, and within the borders of a state which has long maintained an active geological survey, they have been studied now for more than a hundred years. But so varied are they in character, and so complex are their relations to one another, that the working out of their distribution and history has proved to be a very complex and difficult task. They have been a veritable geological and paleontological puzzle, whose solving has demanded the work of several generations of investigators, and which is not yet fully understood. This paper is a small contribution toward its solution.

A century ago, when men first began to study the rocks of eastern North America and the fossils which they contained, the sciences of geology and paleontology were still in their infancy. With no premonition of how difficult the task was going to be, and with a whole new continent awaiting their examination, the early workers usually looked merely at the larger features of the areal geology, and made use of the fossils in only the most general way to determine the relative ages of the strata and the conditions under which they were formed. Thus, when the famous pioneer of North American geology, William Maclure, published in 1809, a paper entitled "Observations on the Geology of the United States," he referred all the rocks of western Vermont to what was then known to geologists as the Transition Class. This class was supposed to contain those rocks which were intermediate in age between the very ancient and the relatively recent strata of the Earth's crust, and corresponded roughly to what we now call the Paleozoic System.[1]

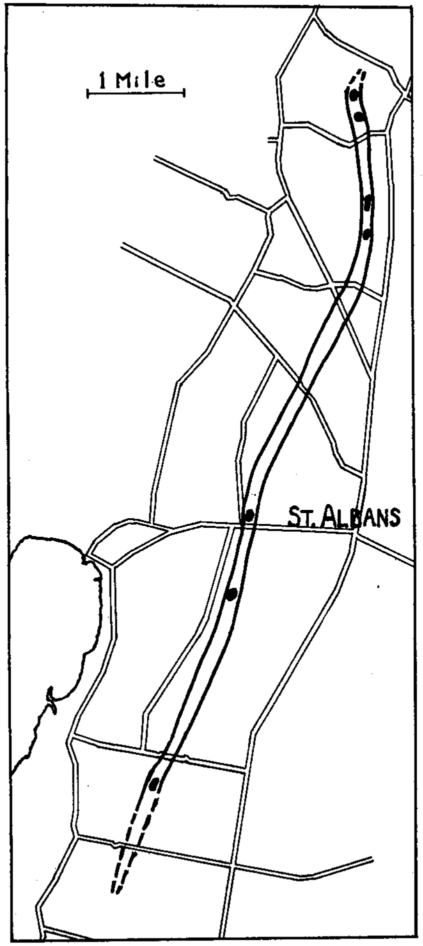

FIGURE 29.—Sketch map of locality of St. Albans Shale.

Maclure was right as far as he went and his work constituted an important first step in our knowledge of Vermont geology, though he classified his rocks in only the most general way.

Little more was learned about the geology of northwestern Vermont for thirty years, except that the celebrated geologist, Amos Eaton, in his "Geological Textbook," first published in 1830, stated that he had found calcareous and quartzose formations along the eastern side of Lake Champlain. In 1848, however, Zadock Thompson, Assistant Geologist of the first state Geological Survey of Vermont, referred beds at St. Albans, to what he called the Red Sandrock Series of the Champlain Group, of the Lower Silurian—or, as we now call it, Ordovician (Thompson, 1848, pp. 45 and 171). In 1842 and 1843 Ebenezer Emmons, who, as a member of the staff of the first Geological Survey of New York, had examined the rocks east of the Hudson River (which are in part a continuation of these of western Vermont), had included the rocks in the vicinity of St. Albans in his new "Taconic System," which he believed to be

[1] Maclure, 1809, p. 422; also 1817a, p. 35, pl. 1, and pl. 2, f. 1; 1817b, p. 49, 50, pl. 1, and pl. 2, f. 1; Merrill, 1906, p. 221 and pl. 1.

the oldest fossiliferous system known; and in 1855 he allocated them more specifically to the system's upper division (Emmons, 1842, p. 136; 1843, pp. 71, 119, 120; 1844, pp. 27, 40; 1855, pp. 49, 50). Neither of these authors referred directly to the beds that are now known to contain a *Paradoxides* fauna; but the strata of which they wrote may have included those beds, although the typical Red Sandrock of the region is older than the *Paradoxides* beds and is exposed a short distance to the west of the belt along which those shales outcrop. It is frequently difficult to determine whether the older authors were referring to our *Paradoxides* beds or not; for they usually did not differentiate them from the rest of what they called the Georgia Slates or the Georgia Group, a set of strata that is now known to include beds of several different ages. In the present paper the writer has tried to include only the references to these Georgia beds that apply to the part of the group which is now known to have been deposited during Paradoxidian time.

While the early American geologists were studying the rocks on their side of the international border in northwestern New England, the eminent pioneer Canadain geologist, Sir William Logan, who organized the Canadian Geological Survey, was trying to unravel the tangled skeins of the Paleozoics on his side of "The Line," in Quebec. His problems were, if anything, even more difficult than those confronting the Americans; and, in an effort to find clues which would help him in their solution, he followed his beds southward into Vermont. When he prepared his map of the parts of Quebec lying north of Franklin County, he extended the colors down into Vermont, covering the country now known to be underlain by the *Paradoxides* beds with the color indicating the Hudson River Group, which was then thought to be a natural assemblage of rocks, but which has since been proved to include a number of Cambrian and Ordovician formations (Logan, 1855). In 1858 Professor Edward Hitchcock, who, with his assistants, made the first systematic study of the geology of the whole state of Vermont, accepted Logan's assignment of these rocks to this group; but, in 1861, when he issued his well-known two volumed final "Report on the Geology of Vermont," he was not so sure about it. He mapped and described the beds in and about St. Albans, and quoted the differing opinions concerning their age that had been expressed by a number of eminent authorities—Ebenezer Emmons, Sir William Logan, James Hall, of the New York Geological Survey, and Joachim Barrande, the famous French paleontologist. He said that he and his son (see C. H. Hitchcock, 1861, pp. 426, 427) had been inclined to consider these beds as younger than the Oneida Sandstone of New York (a Silurian formation), which he thought was of the same age as the

Red Sandrock that underlay them, which we now know to be EoCambrian; but he added that, after reading the opinions of these authorites named above, he did not know what age to call them. He referred the shales in and around St. Albans to his Georgia Group, in which he also included other beds in Georgia, St. Albans, and Swanton townships that are now known to be of EoCambrian, NeoCambrian, and Ordovician age—that is, both older and younger than the *Paradoxides* beds (E. Hitchcock, 1858, p. 10; 1861, pp. 357-386). Fossils had been found at several localities in northwestern Vermont in the older part of the Georgia Group, in strata which have since been proved to be EoCambrian. Some of these fossils were originally described as species of *Paradoxides,* but they are now known to be referable to *Olenellus* and *Mesonacis*. The only fossils that were recorded by Hitchcock from the vicinity of St. Albans were fucoids resembling *Palaeophycus* and a trilobite, not referable to any genus then known in Vermont, but "too indistinct to be named" (E. Hitchcock, 1861, p. 372, including footnote by C. H. Hitchcock). The fucoids were said to occur on "slabs of sandstone" and were almost certainly from a Lower Cambrian horizon; but nothing is said about the character of the rock in which the trilobite was found, and it is therefore possible that it came from the *Paradoxides* beds, though the fact that EoCambrian trilobites are much more abundant than those of Paradoxidian age in that region makes it very probable that this trilobite was also an EoCambrian one. If it really came from the *Paradoxides* beds, it was probably the first fossil of Paradoxidian age to be found in Vermont. Unfortunately the present location of the specimen is not known, so it cannot now be identified.

Hitchcock presented sections of the beds in the vicinity of St. Albans, showing what appeared to him to be their order of superposition. These sections seemed to show that the Georgia Group was of "Middle Silurian" age (that is MesoPaleozoic); but, as the fossils that had been found in it had been declared by Barrande to be of "Primordial" (*i.e.,* Paradoxidian, Cambrian, EoPaleozoic) age, Hitchcock rightly suspected that some faulting or folding must have taken place, although he was unable to find any evidence of such movements (E. Hitchcock, 1861, pp. 373-376, fig. 257, pl. 17, fig. 2). If he had discovered any of the specimens of *Paradoxides* which were hidden in the heart of the Georgia Group he would have been able to prove that some of his beds, at least, were of Paradoxidian age; for Barrande and the Scandinavian paleontologists had already made the *Paradoxides* faunas of Europe familiar to American geologists.

In 1861 and 1862 Jules Marcou, a temperamental Swiss geologist who had emigrated to America, and who had studied the geology of northwestern Vermont, described the rocks of the St. Albans region as green, brown and reddish slates, containing now and then large lenticular masses of very hard whitish-gray limestone. He found no fossils in them, but said that he had heard that a trilobite had been picked up behind the town of St. Albans. He showed a section across the strike of the rocks eastward from St. Albans Bay; but because he misunderstood the structure of the region, his section was incorrect. It is not possible to determine just where Marcou classified all of what we now know as the *Paradoxides* beds, but some of them he may have included in his brown slates, and he probably considered that they all belonged in his St. Albans Group (Marcou, 1861, 1862a, pp. 241, 246). After a second visit to northwestern Vermont, Marcou published in the same year a revised section of the "Upper Taconic" rocks there, in which he increased his estimate of the thickness of the St. Albans group by including in it "the granular quartz and quartzite ...... found at the base of the ...... group," and decreased his estimate of the thickness of the Georgia Slates to 400 feet. The *Paradoxides* beds appear to have been included in the upper division of the St. Albans Group of this last section.

It will be noted that Marcou split Hitchcock's original Georgia Slates into two divisions—the St. Albans Group and the Georgia Slates. He correlated the St. Albans beds at St. Albans with 3,000 feet of strata in the vicinity of Quebec (Marcou, 1862a, p. 248; 1862c.)

In 1861 the American geologist, T. Sterry Hunt, published a paper dealing with the problem of the age of the rocks in the vicinity of St. Albans. He declared that they belonged to the Primordial zone, and correlated them with the *Paradoxides* beds of eastern Massachusetts and Newfoundland, the shales which underlay the Quebec Group near Quebec, and the Potsdam Sandstone. That is, he considered them to be of Cambrian age (Hunt, 1861, pp. 401 and 402). Elkanah Billings, the paleontologist of the Canadian Geological Survey, at this time appears to have believed that the beds at St. Albans were older than the Red Sandrock of the region, which he believed to be of the age of the "Calciferous or Potsdam" (Marcou, 1885, pp. 201-203). In this belief he was wrong, for they are younger.

In 1863 Professor J. D. Dana, of Yale University, in his *Manual of Geology,* and his *Text-book of Geology,* referred the shales in the St. Albans region to the Potsdam Epoch of the Potsdam or Primordial Period (Dana, 1863a, pp. 169-174; 1863b, p. 80); and Sir William Logan mapped them as Potsdam (Logan, 1863, *Atlas,* plates entitled "Geological Map of Canada" and "Map Showing Distribution of Rocks Belonging to the Potsdam, Quebec, and Trenton Groups on the East Side of Lake Champlain"). This "Potsdam or Primordial Period" was roughly equivalent to our "Cambrian Period." At that date the relative ages of its known faunas was not well understood, the *Paradoxides* beds being thought to belong below both the Upper Potsdam and the Lower Potsdam, whereas they really belonged between the two. This erroneous idea arose partly from the fact that no *Paradoxides* Beds had been found in the Cambrian section of Vermont.

In 1867 J. B. Perry classified the rocks of northwestern Vermont below the Calciferous as follows (Perry, 1867):

I. Taconic
- 3. Upper:—Potsdam, in its several divisions.
- 2. Middle:—Black and Brown Slates with Limestones and Sandstones.
- 1. Lower:—Talcose and Talcoid Slates with Limestones and Quartzites (or Conglomerates).

The *Paradoxides* beds were evidently included in his middle division.

In the same year C. H. Hitchcock referred the beds in the vicinity of St. Albans to the Lower Silurian—our modern Ordovician (C. H. Hitchcock, 1867), and Sterry Hunt, laboring under the prevailing illusion as to the relative ages of the Potsdam and *Paradoxides* faunas, wrote, "That strata still older than the Potsdam of New York and Vermont were deposited in some portions of the oceanic area, is apparent from the existence in New Brunswick of the St. John's slates holding a primordial fauna older than the Potsdam, and it is not impossible that their equivalents may underlie the Potsdam of Vermont. No such rocks have, however, as yet, been detected ...... in Vermont" (Hunt, 1868, p. 229). This belief he reiterated in 1870 (Hunt, 1870, p. 83) and 1883 (Hunt, 1883, p. 266). It is evident from his 1883 reference, however, that he included in the "Potsdam" the "Lower Potsdam" of Billings, which, as has been noted, is now known to be EoCambrian—older than the *Paradoxides* beds.

In 1875 Professor Dana referred the beds at St. Albans to the "Potsdam or Georgia" epoch of the "Primordial period" of the "Lower Silurian." Like the other geologists of his day, he believed them to be younger than the strata of the "Acadian epoch" holding *Paradoxides* in Massachusetts, New Brunswick, and Newfoundland (Dana, 1875, p. 167). Sterry Hunt seems to have suspected that this idea of the relative ages of the Potsdam and *Paradoxides* faunas was incorrect, for in 1872, after stating that Billings and Logan had placed their Lower Potsdam above the *Paradoxides* Zone, or "Menevian," he added "Future discoveries may perhaps assign it a place below instead of above the Menevian" horizon (Hunt, 1872a, p. 434; 1872b, pp. 53-55; 1873, pp. 563, 564; 1878a, pp. 406, 407); but most other American geologists seem to have accepted Logan's and Billings' view until Professor Brögger, in Scandinavia, and Dr. Charles D. Walcott, in America, definitely proved it wrong. Had the geologists and paleontologists of those days realized that the fossils of the *Paradoxides* faunas were to be sought *above*, and not *below*, the *Olenellus* beds, such fossils might have been found in the vicinity of St. Albans 60 years ago, instead of only recently.

In 1871 and 1872 Sterry Hunt discussed the differences of opinion that had existed among geologists regarding the age and nomenclature of the rocks of northwestern Vermont (Hunt, 1872a, pp. 420-432; 1872b; 1872c). He suggested that *Paradoxides* beds might sometime be found in the Appalachians, pointing out that fragments of green and black slates, relics of beds of pre-Potsdam age, occurred in beds of quartzose conglomerate at the base of the Potsdam, in Hemmingford, near the outlet of Lake Champlain (Hunt, 1872c, p. 26).

In 1881 Marcou described and mapped the rocks in and about St. Albans. The area which he mapped as underlain by the rocks of his St. Albans Group—a strip running north from Georgia through St. Albans and Highgate Falls to and across the Canadian boundary—is now known to contain beds of Paradoxidian age. Marcou stated that a trilobite that had been identified as *Olenellus thompsoni* (one of the species common in the EoCambrian of Parker's Quarry, northwest of Georgia Center) was said to have been found just east of St. Albans, and that a similar specimen had been found near Franklin. These were probably the specimens which he had referred to in 1862 as specimens of *"Olenus"* (Marcou, 1862c, p. 5, and fig. 1 of plate). He said that he had never seen either of these specimens, and that it was possible that they were true *Paradoxides* (Marcou, 1881, pp. 29, 42); but it is more probable that they were really referable to *Olenellus*. He presented a horizontal section showing what he considered to be the arrangement of the rocks from the shore of Lake Champlain at St. Albans Bay, through St. Albans, to a point east of that village (Marcou, 1881, pl. 2, fig. 2).

In the summer of 1883 Dr. Charles D. Walcott, the eminent authority on Cambrian geology and paleontology, made a careful study of the Cambrian formations in Franklin County, and, with the assistance of Mr. Cooper Curtice, collected many fossils from them (Walcott, 1885, p. 54). Some of these fossils may have come from beds of Paradoxidian age; but, if they did, Dr. Walcott did not definitely recognize them for what they were—members of a true *Paradoxides* fauna.

In 1884 Dr. Theodore Whitfield wrote of the "Acadian beds of Canada and Vermont," (*Acadian* being the name that had been proposed for the *Paradoxides* beds of New Brunswick and Newfoundland) that, in his opinion, they, together with the *Paradoxides* beds of other parts of northeastern North America, were of the same age as the lower portion of the Potsdam Sandstone of New York and Wisconsin. He appears to have included the Georgia beds of Vermont in the Acadian of that state (Whitfield, 1884, pp. 139 and 140). In the same year Whitney and Wadsworth reviewed the works of Hunt and other authors dealing with the older rocks of Vermont (Whitney and Wadsworth, 1884, pp. 440-462); and C. H. Hitchcock, in a cross-section of the strata of the district, marked the *Paradoxides* beds at St. Albans as Cambrian, but did not differentiate them from the other Cambrian strata there (C. H. Hitchcock, 1884, p. 160, pl. 17).

In 1885 Marcou reviewed the work that had been done up to that time on the geology of northwestern Vermont (Marcou, 1885). In speaking of the fossils that had been found in his St. Albans Group, he said again (p. 218), that "the one found near the town of St. Albans, and also at Franklin, may be an *Olenellus* or a *Paradoxides*"; and he added (p. 225), "Let us remember that the St. Albans Group, even at St. Albans or in the neighborhood, has as yet brought nothing certain to palaeontology, ... without doubt fossils are very rare, but let us hope that some day the cutting of roads and opening of quarries will lead to their discovery, especially in the zone which should represent there the *Paradoxides* beds." Marcou then included in the upper part of his St. Albans Group (the lowest main division of the "Taconic System" in northeastern North America) the *Paradoxides* beds of Massachusetts, New Brunswick, and Newfoundland (Marcou, 1885, p. 224). He considered that the New Brunswick *Paradoxides* beds must be regarded as the upper part of the St. Albans Group, "for," he wrote, "the fossils indicate a lower level than the fauna of the "Georgia slates" with *Olenellus*; but they are not far from these; the Brachiopods resemble them very much, and the Trilobites have affinities with them, while they have a facies of greater antiquity, because of the *Paradoxides* and a considerable number of *Concephalites*" (Marcou, 1885, p. 226). At that time paleontologists still labored under the delusion that the *Paradoxides* faunas were older than the *Olenellus* ones.

In 1886 Dr. Walcott described the succession of Cambrian strata found in northwestern Vermont as follows: "At the base of the section a massive belt of limestone, 1,000 feet in thickness, carries in its upper portions the *Olenellus* fauna which, in the argillaceous shales capping the limestones, attains an extensive development. Continuing up in the section through the argillaceous shales, about 2,000 feet, masses of limestones are found interbedded in the shales, and in the limestone fossils that show the near approach of the Upper Cambrian or Potsdam fauna" (Walcott, 1886, pp. 144, 145). It was in the lower part of the 2,000 feet of shales (which he included in his Georgia Formation) that the *Paradoxides* fauna was hidden away; but, keen-eyed fossil hunter though he was, he appears not to have discovered any recognizable trace of it.

In another paper, published soon afterward, Dr. Walcott described and discussed the Cambrian rocks of northwestern Vermont more in detail (Walcott, 1887, pp. 13-24, 44, 49). The *Paradoxides* beds he again included, with others now known to be older and younger in age, in the Georgia Formation. Years later he identified as doubtfully Middle Cambrian (Paradoxidian) certain fossils which he had collected in 1883 from the "St. Albans formation" east of Parker's Quarry (Walcott, 1912, p. 189); but these came not from the *Paradoxides* beds, but from a higher horizon. In 1889, having discovered that the *Paradoxides* faunas were younger than the *Olenellus* ones, but being unaware that a Middle Cambrian *Paradoxides* fauna was concealed in the Georgia shales of Vermont, he assigned all of those shales to the Lower Cambrian (Walcott, 1889, p. 383).

In 1890 C. H. Hitchcock, in the second edition of Macfarlane's *Geological Railway Guide*, referred the shales about St. Albans to the "Potsdam Slate." This he seems to have included in the Georgia Group, which he referred to the Middle Cambrian. He appears to have believed that this Potsdam Slate belonged stratigraphically between the true Potsdam Sandstone of New York, which he thought was younger than the slate, and the *Paradoxides* or Acadian beds of New Brunswick and Massachusetts, which he considered to be older than the slate (C. H. Hitchcock, 1890a, p. 86; 1890b, pp. 92 and 93). Some of the shales near St. Albans are of the age he assigned to them, though the *Paradoxides* beds there are older, and some of the other beds are younger. In the same year, S. A. Miller referred our beds to the Georgia Group of the "Taconic System," which group he also believed to belong stratigraphically below the Potsdam Group and to be correlatable with the *Paradoxides* beds of the St. John Group of Massachusetts, New Brunswick, and Newfoundland (Miller, 1890, pp. 16, 22-29).

In this year also Marcou again discussed the age of the beds around St. Albans. He placed them in the lower half of the "Middle Taconic," and came to the conclusion that, while they probably represented "stratigraphically and lithologically all the lower parts of the *Paradoxides* zone containing the large *Paradoxides*, such as *Paradoxides harlani*, *Par. regina*, *Par. bennetti*, and *Par. davidis*, and also the *Holmia* zone and even the *Schmidtia* zone," this correlation could not be proved until they had been explored and studied carefully (Marcou, 1890b, pp. 86, 91, 227, 228). The *Holmia* and *Schmidtia* zones had been stated by Dr. Walcott and other geologists to be of pre-Paradoxidian age, and are so considered by most geologists at the present time.

Marcou conceived that there existed in Paradoxidian time two separate seas, which he called the Acadio-Russian and the Nevado-Canadian seas, and which were separated by a narrow isthmus, which extended from Newfoundland to Nova Scotia and thence through Maine, New Hampshire, and western Massachusetts, to southeastern New York, New Jersey and the states bordering the Atlantic Ocean farther south. The *Paradoxides* beds of Newfoundland, New Brunswick, and Massachusetts he believed to have been formed in the Acadio-Russian ocean, while the beds of the St. Albans and Georgia groups of Vermont he thought had been laid down in the Nevado-Canadian sea. He thought that the *Olenellus* fauna of Vermont and northern Newfoundland was of approximately the same age as the *Paradoxides* faunas of Massachusetts, New Brunswick, and southeastern Newfoundland, and that it differed from them because it lived in a different oceanic basin. In this he was wrong, for the *Olenellus* fauna is older than the *Paradoxides* ones. However, as was mentioned above, he considered that a *Paradoxides* fauna might have lived in the Nevado-Canadian sea of northwestern Vermont at some time (Marcou, 1890a, pp. 357, 358, and map facing p. 357; 1890b, pp. 86, 87, 90-92, 224-228, 232). Of his St. Albans Group he wrote that it "was created to place in it all the strata existing between the band of the Georgia slates or formation in Franklin County, Vermont, eastward of Parker's farm outcrop, and the talcose slates and conglomerates of Fairfield." He added, "Although there have been reports that large trilobites have been found in two places, east of St. Albans village and Highgate Falls village, no specimens have ever found their way into the hands of paleontologists, or reliable practical geologists ......; and in that great mass of stratified rocks, fossils, although rare, can be found when they are carefully explored by fossil collectors and resident stratigraphists." He stated further that "in the St. Albans group, near the base, in the vicinity of the Georgia railroad station, true argillite slates are found, as at Braintree and St. Mary's bay, and there is no reasonable doubt that one day or another primordial fossils and more especially large trilobites of Paradoxidian forms will be found in the St. Albans group of Vermont, Canada, and Maine." His prophecy has now come true for Vermont, though not yet for Canada and Maine.

In 1891 Dr. Walcott, who had by that time discovered that the *Paradoxides* beds were of Middle Cambrian age, referred the main mass of the Georgia Slates to the Lower Cambrian, but stated that a lentile of limestone, found interbedded in the upper

part of the slate, contained fossils that might "prove to be a portion of the Middle or it may be the Upper Cambrian fauna" (Walcott, 1891a, pp. 531-534, text fig. 50, and pl. 44). This lentile is now known, however, to be of later age. In another paper, published in the same year, he again referred the lower part of the Georgia Shales to the Lower Cambrian, stating that their upper beds, together with certain limestone masses interbedded in them, contained fossils that might prove to be Middle or Upper Cambrian; and he presented a columnar section of the Cambrian strata of Franklin County, in which he showed both Middle and Upper Cambrian beds (Walcott, 1891b, p. 311, text fig. 2 and pl.; 1891c, pl. 42).

In 1898 Dr. Walcott described a new species of brachiopod, *Obolus* (*Lingulella*) *franklinensis,* from the "Middle (?) Cambrian, St. Albans shale, in limestone lentile a little west of the town of Georgia, about a mile east of Parker's quarry; also a mile SSW. of Highgate Falls." He stated that, in the absence of definite proof of the exact age of the beds containing this brachiopod, he had assigned them provisionally to the Middle Cambrian because they contained species of *Agnostus* and *Ptychoparia* (Walcott, 1898, pp. 404-405). He there used "St. Albans" as a formation name, in a much more restricted sense than the one in which Marcou had used it.

In 1902 Dr. E. O. Ulrich and Professor Charles Schuchert, in a discussion of the Paleozoic Seas and barriers in eastern North America, stated that during Middle Cambrian (Paradoxidian time) the Levis Channel, which they supposed to have been an old sea-way, running up the Hudson and Champlain valleys, was occupied by a strait that connected with a Mississippian sea (in which *Paradoxides* faunas are not known ever to have lived), but not with the Atlantic Ocean, the home of the *Paradoxides* faunas (Ulrich and Schuchert, 1902, pl. 9, and table facing p. 658; 1903, pl. 9, and table facing p. 658).

The discovery of a *Paradoxides* fauna in Franklin County indicates that this channel was connected with the Atlantic during the Middle Cambrian.

In 1903 Dr. Walcott seems to have obtained some brachiopods from the *Paradoxides* beds at St. Albans, though he appears not to have published a notice of the fact until 1912 (Walcott, 1912, p. 187, 548). In 1905 he described a new brachiopod, *Syntrophia billingsi,* from a lentile of limestone interbedded in siliceous shales above the *Olenellus* shales, one mile east of Parker's Quarry (Walcott, 1905, pp. 291-292). He then referred the beds to the Upper Cambrian; but in 1912 he stated that they were more probably of Middle Cambrian age (Walcott, 1912, pp. 189, 806). They are, however, more recent than Paradoxidian.

Thus, in spite of the fact that some of the most distinguished and able geologists and paleontologists of the United States and Canada had studied the Cambrian strata of Franklin County in an effort to learn their age and relationships, they had all failed to discover the interesting fact that some of the shales there held a true *Paradoxides* fauna. It remained for a local naturalist, Mr. G. E. Edson, of St. Albans, to gather the first real evidence of this fact. He found and collected the first fossils from these shales that were to come into the hands of a paleontologist who could recognize them for what they were—Dr. Walcott. Mr. Edson gave the fossils to Professor Perkins, State Geologist, and he sent them to Dr. Walcott for identification. Dr. Walcott recognized them as members of a *Paradoxides* fauna; but it was some time before the discovery was announced in print.

In 1906 Mr. Edson described the character and distribution of the limestone conglomerates and associated shales of St. Albans and vicinity, and recorded the finding "in shale in the intraformational conglomerate on the west side of St. Albans," of the brachiopod, *Lingulepis acuminata,* a species previously found in beds of "Upper Cambrian" age at other localities in northeastern North America (Edson, 1906, pp. 152-154). He also reported finding this brachiopod and a trilobite, *Agnostus,* in blocks of glacial drift in the same vicinity. The last of these fossils, at least, was of Paradoxidian age; but the fact was not recognized at the time. The *Paradoxides* shale at the locality where the fossils were found —Adams' pasture, in the western outskirts of the city—looks (probably because some large blocks of it have been moved short distances by the Pleistocene glaciers) as though it was interbedded with the limestone conglomerate; but it really underlies the conglomerate unconformably.

In 1908 Mr. Edson, in an account of the geology of Swanton township which lies just north of St. Albans, again referred to the finding of fossils in this shale. He there stated that the shale is found below, in, and above the conglomerate, and that the same fossils occur, at all three of these levels (Edson, 1908, pp. 213, 214). Later researches indicate that the *Paradoxides* fauna is found in place only in the shale *beneath* the conglomerate; and that the conglomerate and the shale which overlies it hold younger, NeoCambrian fossils. In the same volume in which Mr. Edson's report appeared ("Report of the Vermont State Geologist for 1907-1908") Professor Perkins announced (pp. 208, 209) that Dr. Walcott had recognized *Paradoxides* in pieces of the shale collected by Mr. Edson, and that it could now be definitely stated that Middle Cambrian, Paradoxidian, strata surely existed in Vermont.

This was an announcement of more than ordinary interest to American geologists and paleontologists, for, as has been previously noted, geologists had been generally agreed up to then that the Cambrian strata of Vermont had been deposited in an arm of a sea which lay to the west and which was inhabited only by "Pacific" faunas, while the *Paradoxides* faunas were thought to have been confined to the North Atlantic Basin, having been found in North America only in eastern Massachusetts, southern New Brunswick, and southeastern Newfoundland.

In making this announcement Professor Perkins wrote:

"In the intraformational conglomerate mentioned by Mr. Edson in his article on the Geology of St. Albans, Fifth Report, page 143, there are well-defined fossils which have puzzled us for some time. These are not at all abundant in the conglomerate, and when found are not easy to get out, but by diligent search Mr. Edson has succeeded in obtaining quite a collection. Dr. Walcott, during his work in the region also secured fossils from this part of the strata. Hitherto no study has been given to these fossils, but a short time ago I took selections of them to Dr. Walcott. On looking over the collections at Washington numerous specimens were found which had come from the same locality. Dr. Walcott gave them a preliminary examination and expected to furnish a list for this report, but has not been able to do so. He writes, as a result of his brief preliminary investigation:

" 'The fauna is Middle Cambrian, as indicated by its general facies, and also by the presence of *Paradoxides*. Thirteen species are noted. One of the interesting occurrences is the presence of *Paradoxides* in the argillite. If this is the matrix of the conglomerate, it locates the horizon and also proves that the conglomerate is interformational.'

"While Dr. Walcott does not wish to commit himself as to the specific identification of these fossils, he sends the following list of genera: *Obolus, Lingulella, Hyolithes, Leperditia, Agnostus* (two species), *Agraulos, Menocephalus, Ptychoparia* (three species), *Anomocare, Paradoxides*.

"It appears very probable that many of the species are undescribed. The important point for the present, however, is the determination of the beds as Middle Cambrian, as no fossils of this period have heretofore been recognized in this state, although it has seemed almost certain that this part of the formation must be represented in our Vermont strata."

As this quotation shows, although *Paradoxides* fossils had been finally and surely located in Vermont, there was still some doubt as to just which beds had yielded them. The approximate position of the beds containing them was known; but their exact place in the Cambrian stratigraphic section of the region had still to be determined. The thickness and areal extent of the beds had also to be determined, as well as their relations to the formations above and below them, while larger collections of their fossils were needed to show their exact age.

In 1910 Dr. Walcott identified the specimens of *Paradoxides* which Professor Perkins had sent to him from the St. Albans shales just west of St. Albans as *Paradoxides harlani,* a form known previously only from Braintree, in eastern Massachusetts. He described the St. Albans shales as being argillaceo-arenaceous, and carrying lentiles of limestone that are more or less fossiliferous. He stated that the *Paradoxides* occurred both in the shale and in a limestone lentile, and that it was accompanied in the limestone lentile by an *Agraulos*. He figured one *Paradoxides* head from the shale and another one from the limestone (Walcott, 1910, pp. 254 and 255, figs. 10 and 11). Here again, as in 1898, he apparently used "St. Albans" as a formation name, and in a much more restricted sense than Marcou had originally used it years before.

Professor Schuchert, commenting in the same year on the presence of a *Paradoxides* fauna at St. Albans, wrote, "This fact shows how near the Atlantic waters approached those of the Pacific realm on the western side of the Green Mountain barrier without intermingling." He added that the present position of the beds in that region was "due to much northwesterly thrusting" (Schuchert, 1910, pp. 521-522).

In 1912 Dr. Walcott, in his great monograph on the Cambrian brachiopods, recorded three species, *Obolus matinalis, Huenella vermontana,* and *Paradoxides sp.* from Middle Cambrian beds of the "St. Albans formation" at St. Albans, stating that the *Huenella* occurred in association with *Paradoxides* in an intraformational conglomerate. At the same time he listed three other species, *Lingulella franklinensi, Huenella billingsi,* and *Ptychoparia adamsi,* from beds of "Middle? Cambrian" age, in the St. Albans formation, in a limestone lentile about one mile east of Parker's Quarry (division 9 of his 1887 section, and probably one of the localities referred to by him in 1898 and 1905). Of these three species, one (the *Huenella*) was new and known only from that locality and formation, another (the *Lingulella*) had been found near Highgate Springs and Highgate Falls, north of St. Albans, in beds whose age Dr. Walcott gave as Lower Cambrian on pages 217 and 251, Middle Cambrian on page 502, and doubtful on page 102, and the third (the *Ptychoparia*) was a common fossil of the Lower Cambrian of northwestern Vermont. The *Lingulella* and the two species of *Huenella* were figured and described. An *Agnostus* and a *Ptychoparia,* were said to occur in the same beds with the *Lingulella* (Walcott, 1912, pp. 100, 102, 109, 115, 116, 119, 159, 189, 251, 402, 501, 502, 806, 809, text fig. 76, pl. 26, figs. 3, 3a, b. pl. 102, figs. 5, 5a-c). Some of these fossils were undoubtedly from the *Paradoxides* beds, others will almost surely prove to have come from the overlying NeoCambrian beds.

In this same year (1912) Professor Perkins stated that the only well-established outcrops of Middle Cambrian strata in Vermont were in a calcareous conglomerate in a small area in St.

Albans in which a hard limestone occurs in a conglomerate, which contains Middle Cambrian fossils. He added, that the matrix as well as the included bits of this conglomerate are of Middle Cambrian age, and that the formation does not so far as made out, cover very much of the area of Franklin County (Perkins, 1912, pp. 17, 24). In this he was correct, except that the fossils occur properly not in the conglomerate, but in the shale below it.

In 1921 Professor C. E. Gordon, who was then studying the geology of western Vermont, discussed the Middle Cambrian beds of the northwestern part of the state, referring to their discovery and description by Mr. Edson, and to the identification of *Paradoxides* in them by Dr. Walcott. He suggested that deposition of Cambrian sediments might have continued during all of Middle and part or all of Upper Cambrian time in that region, after which he thought that a disturbance might be thought of as having folded or otherwise deformed the Cambrian beds and raised them above the sea. He hazarded the opinion that the structural relations between the *Paradoxides* beds and the other Cambrian rocks might prove to be complicated and possibly abnormal in some cases, and suggested the possibility that the "so-called conglomerate" of the *Paradoxides* beds might be "an autoclastic" (Gordon, 1921, pp. 131, 132, 265).

In 1923, Dr. Arthur Keith, of the United States Geological Survey, who, with Professor Schuchert, had been studying the rocks of northwestern Vermont for several years, published a very important paper on the geology of that region (Keith, 1923), in which he described and discussed in detail the stratigraphical succession of the Cambrian and associated beds. He divided the Cambrian strata into a number of new formations. His paper marked a very great step forward in our knowledge of the geology of Franklin County. He did not, however, know just what to do about the *Paradoxides* beds; which had been reported to exist there; for he had not been able to find any fossils of a *Paradoxides* fauna in the field, and Mr. Edson was no longer living to show him where he had found the ones which he had collected. He tentatively included the beds in the formation which he called the Highgate Slate. His description of this slate is summarized as follows: three hunderd feet or more of dark, generally black, slate, usually banded, interbedded with thin seams of blue limestone; several beds of tough gray dolomite, a foot or so thick, in the lower part in at least one locality; interbedded limestones increased in thickness to form a banded limestone mass, 35 feet thick, at another place; and good-sized lenses of limestone at other localities; fossils of "Upper Cambrian" age. As the *Paradoxides* beds had a limited areal distribution, lay stratigraphically only a few feet below the true Highgate shales, and were almost identical with them in appearance, it is not surprising that he failed to recognize them for what they were.

Beneath the Highgate Slate Dr. Keith described the Milton dolomite, eight hundred feet and less of massive dolomite, varying in color from dark bluish-gray to buff, with some beds of sandy limestone and a few beds of dolomitic sandstone, together with numerous irregular patches of black chert and beds of conglomerate that consisted principally of pebbles of gray dolomite and dolomitic sandstone, with a few, usually angular, pebbles of black slate, all in a dolomitic matrix. The lower part of this formation he thought to be possibly of Paradoxidian age; but the whole of it is probably older.

Dr. Keith stated that Upper Cambrian fossils occurred in the Milton dolomite, but this record was based on an error, whereby certain Upper Cambrian fossiliferous beds were wrongly correlated with the true Milton. No fossils have been found in the original Milton, and we do not know certainly whether it is of Paradoxidian age, or older, though, as it seems to underlie the *Paradoxides* beds either unconformably or disconformably, it was, as has been said, probably laid down in pre-Paradoxidian, late EoCambrian, times.

The shales beneath the Milton dolomite Dr. Keith named the Colchester Formation. This formation has yielded many fossils of the EoCambrian *Olenellus* fauna in Vermont—especially at the famous locality, Parker's Quarry. Dr. Keith thought that the *Paradoxides* fossils collected by Mr. Edson might have come from this Colchester Formation. In his description of the Colchester he wrote: "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 (Keith, 1923, p. 112). And in his discussion of the age of the Milton dolomite he stated, "*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" (Keith, 1923, p. 144). As we now know, the Middle Cambrian *Paradoxides* beds form a distinct formation above the Milton.

In the summer of 1922 the writer spent a month studying the *Paradoxides* beds in the vicinity of St. Albans. He collected a number of species of brachiopods and trilobites (including a species of *Agnostus* and fragments of what appeared to be a species of *Paradoxides*) from the conglomerate and the overlying shale in Adams pasture, in the western outskirts of St. Albans, where Mr. Edson had found the specimens which Dr. Walcott (1910, pp. 254, 255) had identified as *Paradoxides harlani;* but he did not determine what was the exact stratigraphic position of the beds. He also collected from a limestone pebble in a conglomerate at Skeels Corners, four miles south of Highgate Falls, what appears to be possibly the anterior portion of a cranidium of a small example of *Paradoxides harlani.* As noted above, Dr. Keith was not certain to which of his formations the beds at St. Albans belonged; but the outcrop of conglomerate at Skeels Corners is probably one of those which he included in his Swanton Formation. Professor Schuchert examined these fossils at Princeton in October, 1922, and communicated the results of his examination to Dr. Keith before the publication of the latter's paper. Professor Schuchert and Dr. Keith then made a detailed search for further evidence of the exact stratigraphic location and areal distribution of the beds. They found that they lay between the Milton Dolomite and the Highgate Slate and that they extended for several miles north of St. Albans and for at least a mile south of that city. Later the writer examined them more thoroughly, went over them with Professor Schuchert and Dr. Keith, and collected many fossils from them. A brief statement of what he learned was published in 1926 (Howell, 1926a, 1926b). The present paper tells in more detail what he has been able to discover about the beds, themselves. In a future paper he will describe the fossils which have been found in them.

The writer proposed in 1926 that the old name, St. Albans, be restricted to the *Paradoxides* beds of Franklin County, and used as a regular formation name, with a definite meaning. It has been used before in a larger sense, but only a few times; and it is the most logical—almost the only appropriate—name available for those beds. It is used in that sense in this paper.

The St. Albans Shale is, as its name implies, composed principally of mudstones. Many of its beds are, however, so limy as to deserve the name of limestones; and thin layers and lenses of sandstone occur here and there throughout the formation. Some of the beds are fine-grained black shales, but the majority are dark gray and coarser grained, sometimes so micaceous as to be golden brown in color, and sometimes sandy. The more limy strata tend to be blue gray in color. They vary from limy shales to impure limestones; but the limestones are always mere lenses—never beds.

The matrix of the sandstone layers is also frequently limy. The whole formation seems to have been thin bedded, and was at least in part banded; but the cleavage has done so much to destroy the evidence of the original bedding and banding that no more definite statement than this regarding those features can be made. The beds are not as well banded as are those of the Upper Cambrian Highgate Shale, which often occur near them in the field. No evidence of cross-bedding on any considerable scale was seen in the main body of the formation.

The contact of the St. Albans with the underlying Milton Dolomite and the overlying Mill River Conglomerate[1] is not known to be anywhere really well exposed. This lack of good exposures, and the great amount of thrusting that has shifted the beds about and perhaps thrust them in among one another, has made any certain determination of the nature of these contracts very difficult, if not impossible of accomplishment. If the writer has correctly interpreted the field evidence which he has seen, it would seem to indicate that the contact with the underlying Milton Dolomite is probably disconformable; but such evidences as the writer has discovered is by no means conclusive on this point. There is at some localities seen at the base of the St. Albans shale a one or two foot bed of sandy dolomite, sometimes containing small pebbles of blue limestone; and this bed may be conformable with the overlying shale and be part of the St. Albans Formation, rather than of the Milton, though it resembles the Milton. It is also barely possible that even more of the dolomite beneath the shale in the northern part of the *Paradoxides* beds belt is basal St. Albans, no Milton being present there. At one place, north of St. Albans, what appeared to be a small flat pebble of dolomitic sandstone was found in one of the basal beds of the St. Albans. Furthermore, the upper surface of the Milton, beneath the St. Albans, appears to be an uneven one, and the Milton varies greatly in thickness, being sometimes almost absent north of St. Albans. No difference in dip and strike has been detected between the Milton and the St. Albans; but even if one exists, it will be difficult, if not impossible, to demonstrate, because of the cleaving and overthrusting which have affected the St. Albans.

The relation between the St. Albans Shale and the overlying Mill River Conglomerate are equally difficult to determine. At only one place (at the type locality of the Mill River Formation) can the contact be seen at all. There it appears almost surely to

[1] This is a new name, here proposed by the writer, after consultation with Dr. Keith, for the conglomeratic limestone which overlies the *Paradoxides* Beds and underlies the Highgate Shale. Its fauna has not been carefully studied; but it is believed to be of NeoCambrian age. The name is taken from Mill River, just east of which the formation is exposed about two miles southwest of St. Albans, a quarter of a mile south of the road running west from the western foot of St. Albans Hill.

be an erosional one, though there may be little or no difference in the strike and dip of the two formations. As the Mill River Conglomerate is probably of Upper Cambrian age, however, there is presumably a sedimentary break above the St. Albans Shale throughout the whole region where it has been found.

Because of the shearing, which has masked the bedding, and on account of the movement which caused the shearing and has shifted the beds to an undeterminable extent, it has not been possible to get any satisfactory measurements of the present thickness of the St. Albans Formation. Perhaps the best estimate of the maximum thickness actually exposed would be 200 feet. This is a very rough estimate of the thickness at a point about a mile and a half southeast of Swanton Junction. It is probably less than this at some places, and more at others. Whether these are approximately all the *Paradoxides* beds that were ever deposited in the region, we can not now determine; though the apparent absence from the Mill River Conglomerate of pebbles holding a later Paradoxidian fauna would appear to argue against the deposition of much later beds during Paradoxidian times.

Lithologically the St. Albans Shale closely resembles the younger Highgate Shale and some parts of the older Colchester Formation. It is usually a little lighter gray in color and less distinctly banded, and is coarser grained and heavier bedded than the Highgate, which is, on the average, more slaty and schistose. It is finer grained and less heavy bedded than the shales of the Colchester, which tend to be more golden brown, olive, or rufous in color, and which break into larger pieces than do the St. Albans ones. These distinctions do not always hold, however; and, since the Milton, Mill River, and Swanton formations are also frequently difficult to distinguish in the field, it is necessary for one to find fossils of a *Paradoxides* fauna in his shales if he is to feel certain that he has the St. Albans Formation.

The known exposures and deduced extent of the St. Albans are shown on the map which accompanies this paper. The lithologic similarity between the beds and those of the older Colchester and the younger Highgate formations, the scarcity of recognizable fossils, the thrusting which has shifted the beds of northwestern Vermont varying distances to the west, and the ease of erosion of the St. Albans shales as compared with the strata lying adjacent to them, which has resulted in their being gouged out and buried beneath Pleistocene glacial deposits, make it impossible for us to determine their exact areal distribution, and make the attempt at an approximate mapping of them which is here presented little better than one of the most probable guesses that can be made with the information now available. New evidence will probably enable future workers to map the formation more accurately. The beds are now known definitely to occur at certain places, as shown on the map. They presumably extend between these places approximately as indicated. It is the extention north and south of this definitely determined area that is so largely in doubt.

Since we do not know the original areal extent of the St. Albans Shale nor the character of its on-shore and seawardmost beds, we are forced to depend entirely upon the composition and arrangement of what is presumably part of the main body of the formation for evidence of the conditions under which all of its deposits were originally accumulated. This evidence seems to the writer to indicate that the beds were laid down in shallow water, not very far from a rather low-lying land. The lower beds may have been deposited a little nearer to the shore than were the higher ones; but no good evidence of this was seen. The transition from the underlying Milton Formation to the St. Albans, while it may barely possibly have been an unbroken one, with continuous deposition, is nevertheless rather abrupt, and the basin may have sunk rather quickly, so that the St. Albans muds were laid down farther off-shore than the Milton beds, while the dry land near the shore may also have been lower in St. Albans time than it had been during Milton time, and may have had a different climate also.

Sometime after the deposition of the Paradoxidian St. Albans muds, and before the laying down of the presumably Upper Cambrian Mill River Conglomerate, the sea bottom of which the St. Albans shale then formed a part was raised above sea level and eroded. As we do not know how much erosion took place—how many beds were completely destroyed—we cannot now determine when deposition stopped and erosion began. As already mentioned, the apparent absence of any known pebbles containing a middle or late Paradoxidian fauna from the Mill River Conglomerate would seem to argue against any later Paradoxidian deposits having ever been laid down; so it seems probable that not very long after St. Albans time the St. Albans shales were lifted above the sea. They surely underwent erosion until sometime in the Upper Cambrian Epoch, when they were depressed beneath the surface of the ocean and covered over by the Mill River deposits. These, with the overlying strata, protected them from further erosion until the latter part of Ordovician time. Then the Taconic Revolution folded and sheared both them and the overlying rocks, and inaugurated the erosion which has continued ever since (as far as we can judge), until there remains exposed today only a cross-section of one part of their original mass, outcropping here and there through the mantle of glacial deposits, in the form of much sheared eastward dipping shales, most of whose

fossils have been destroyed by cleavage except at places where the cleavage has happened to be parallel to the bedding.

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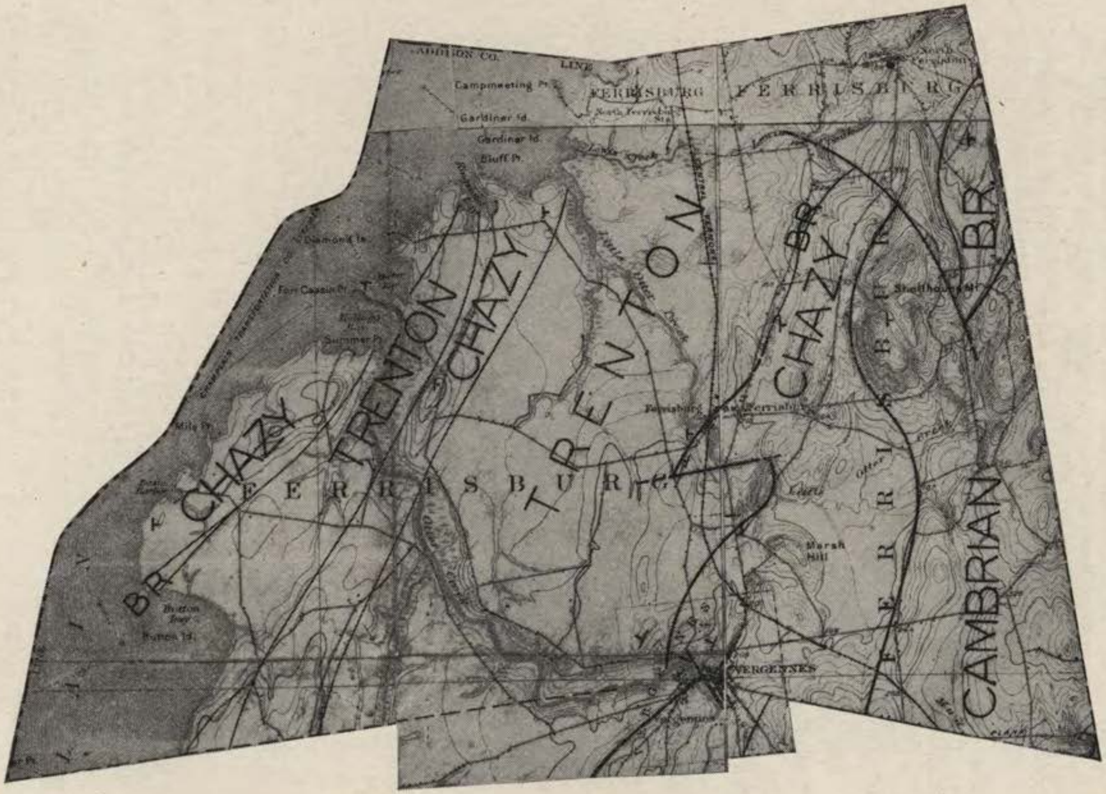

FIGURE 30.—Geological map of Ferrisburg.

THE STRATIGRAPHY OF FERRISBURG, VERMONT

EDWARD J. FOYLES

INTRODUCTION

This paper continues the description and mapping of the Cambrian and Ordovician sediments in the townships of Addison County. While the studies of the geology of Addison County were originally undertaken in an attempt to determine the age relationships of the strata, it was thought best to prepare maps of the areal geology of each township studied in order that they might eventually be used in the preparation of a complete geological map of the State. Consequently, maps of Shoreham, Bridport, Addison, and Panton have been prepared. This is in conformity with the work of Richardson and others working on the terranes of the east side of the Green Mountains.

In my studies of the rocks in the townships south of Ferrisburg, the Cambrian, Beekmantown, Chazy, Black River, and Trenton sediments have been observed to extend generally north and south in parallel strips. The strata of Ferrisburg are no exception to this rule, but it is noteworthy that the Beekmantown disappears north of Shoreham and does not reappear until we reach Charlotte. If the Beekmantown occurs between Shoreham and Charlotte in western Vermont, it will possibly be recognized as part of the so-called Cambrian in the Vermont valley. Extensive outcrops resembling the Beekmantown sediments are to be seen in northwestern Leicester. In Ferrisburg higher facies of the Trenton are found than anywhere to the south.

DISTRIBUTION OF THE SEDIMENTS

TRENTON

In the process of mapping five townships in Addison County bordering Lake Champlain, the Trenton has appeared to consist of four distinct facies, lying in parallel strips of general north-south strike.

Cobourg Limestone.—Uppermost, and exposed in very few places on the border of Lake Champlain, we find the Cobourg. This facies is encountered principally at Fórt Cassin at the mouth of Otter Creek. It is found again at Long Point (Campmeeting Point) in Ferrisburg; and the Cobourg may also be seen in the rocks of Providence Island. The Cobourg is probably present in Shoreham, but its existence there is not definitely known. The Cobourg is 9+ feet in thickness. In places the Cobourg has been faulted onto the Chazy. Its dark, almost black, appearance and a Fusispira and Hormotoma fauna are aids in its identification.

The rocks at Campmeeting Point (now called Long Point) have been considered in the past as fossiliferous Chazy limestone forming a low anticlinal fold. No fossils from this locality have ever been cited specifically. In the summer of 1926 the writer searched the ledges on the shore for fossils and was rewarded with one discovery. This was a brachiopod which has been identified as *Triplecia nucleus* (Hall). This is a Trenton fossil. The matrix is similar to the Trenton of Fort Cassin Point farther south, and since Trenton shales occur directly east of this locality, it is not surprising that the rocks of Long Point should prove to be in part Trenton. On the other hand Long Point is directly in line with the central band of Chazy, and it is thought best to map it mostly as Chazy until more evidence is found.

Canajoharie Shale.—Below the Cobourg lies a black shale yielding *Glyptograptus amplexicaulis* (Hall) and *Dalmanella rogata* (Sardeson). This shale is recognized as the Canajoharie; and it has been found in northwestern Bridport, western Panton, and western Ferrisburg. Graptolites are typical of it.

The village of North Ferrisburg is situated in a hollow in the Canajoharie shale. The position of this shale is the key to the contact between the limestone and the shale, and the thickness of the limestone may be approximately determined for the first time, the figure arrived at being 1,650 feet. This is probably a high figure.

East of the black Canajoharie shale and presumably lying beneath it there is a band of limestone which is determined as the Glens Falls by the large number of lace-collar trilobites, *Cryptolithus tesselatus* (Green), and *Plectambonites sericeus* (Sowerby). *Prasopora simulatrix orientalis* (Ulrich) indicates by its abundance that the rock may be typical Trenton.

Addison Formation.—In the central part of the township there is a broad flat valley covered with Champlain clays through which protrude occasional knots of shale and calcilutyte. The transition from the limestone to the shaly limestone and shale is imperceptible. No contacts have been seen, but the change in kind of sediment is evident, not only from the slabs and concretions seen in the outcrops, but by the valley formed by the rapid erosion of its substance, a valley that is partly disguised by the filling of clay. This shale is sometimes crossed by the cleavage lines of slate. No fossils have been found in the shale by the writer during six summers of exploration, nor have any fossils ever been reported from it. Since this broad band of sediment appears to be so distinct through five townships it is proposed to distinguish it by the name of Addison shaly limestone. It is considered to be a local facies equivalent in age to the Canajoharie.

In Bridport the Addison formation may be seen in alternating bands of thick (1″) and thin (¼″) layers which are crossed by the cleavage planes of slate. Concretions were found in the formation which in some places was crossed by thin layers of lime, indicating faults cemented by calcite.

Glens Falls Limestone.—The lowest part of the Trenton is a limestone interbedded with shale, carrying *Cryptolithus.* This rock is exposed in Ferrisburg along the base of the Cambrian escarpment in the northeast part of the township and extending from there southwest to Vergennes.

From Vergennes northward the Glens Falls phase of the Trenton limestone may be seen along the contact with the Chazy. On the hill which is skirted on the northeast by the Little Otter Creek, *Cryptolithus tesselatus* (Green) and *Calymene senaria* (Conrad) were observed. Three-fourths of a mile north of Ferrisburg, *C. tesselatus* may be seen in the dark limestone. This specie is found again in the limestones on the south slope of Shellhouse Mountain.

BLACK RIVER

The Black River may be seen southeast of North Ferrisburg along the eastern border of the township. Where observed, the strata dip 30° east. *Columnaria halli* (Nicholson) was found on the hill one mile southeast of North Ferrisburg. Two miles north of Ferrisburg on the main highway the Black River lies conformably upon the Chazy in beds striking N 20°. Although *Columnaria halli* (Nicholson) was observed in the rock, it should be noted that this coral may not certainly indicate the Black River, and that the beds here referred to that age may be Chazy in age.

The Black River occurs also at Button Bay where the rocks yield a characteristic fauna.

CHAZY

The Chazy rocks extend in three broad bands from southwest to northeast across the township. The western band consists of beds which dip to the east and whose strike is north-south, while the trend of the outcrop is northeast. The fossils indicating the age of the beds are *Maclurites magnus* (Lesueur) and *Girvanella ocellata* (Seely). The central band is roughly parallel to the first and yields *Maclurites magnus* (Lesueur). The eastern band extends northeast from Vergennes, and ends abruptly at a fault a mile south of North Ferrisburg.

As one goes eastward from the Chazy outcrops near the lake, he crosses a broad flat of Champlain clay underlain by Trenton (Addison) shale. Halfway across the township he is confronted with a scarp of the Chazy which rises in bluffs a hundred feet above the plain. Still further eastward the Cambrian quartzites and dolomites overawe all the rocks in the township.

A specimen of *Maclurites magnus* (Lesueur) from the rocks of Bluff Point indicates the middle Chazy. This species has also been found near the road from Kingsland Bay to Ferrisburg, at the bend of the road about two-thirds of a mile east of the bay. The beds dip gently eastward. Southward from the cross-road near Kingsland Bay the Chazy limestone may be observed forming a ridge which attains 230 feet in height. One-fifth of a mile northeastward on the road to Fort Cassin shales occur yielding graptolites which are probably Trenton. One mile further on the Trenton of Fort Cassin may be seen.

The Chazy extends through the approximate center of the township from south to north, but is lost sight of a mile south of North Ferrisburg. East of the road from North Ferrisburg to Ferrisburg the scarp of the Chazy limestone dips 50 degrees to the east. The boundary between the Chazy limestone and the Trenton limestone is quite marked. One-half mile west of Ferrisburg the Chazy is faulted over onto Trenton shale, and the dip is 30 degrees east. One mile southwest of Ferrisburg the Chazy dips 30 degrees to the west. In Marsh Hill the structure of the Chazy is not easily determined, but it is suggested that it lies in the form of a low anticline.

In the north-central part of Vergennes the Chazy appears to lie as a syncline, the west limb dipping 10 degrees east, and the east limb dipping 34 degrees west. These rocks yield *Maclurites magnus* (Lesueur) and *Girvanella ocellata* (Seely). One mile east of Vergennes is an outcrop resembling Bird's-eye limestone.

BEEKMANTOWN

Rocks of Beekmantown age are not certainly known to occur in this township. The rocks of Fort Cassin have long been considered to be of that age, but there is much evidence to indicate that this is not the fact. It is thought that the Fort Cassin strata consist of Trenton and Chazy beds, with the very doubtful occurrence of Beekmantown.

CAMBRIAN

In the eastern part of the township the Cambrian rocks have been carried by thrust faulting onto the Chazy and Trenton beds. The western strip of this rock is composed largely of quartzite of Monkton age. Along the east border of the township the rocks contain considerable dolomite. No fossils have been found in the Cambrian of Ferrisburg.

IGNEOUS ROCKS

In the bed of Lewis Creek south of the bridge at North Ferrisburg there occurs a porphyritic dike which is described by Professor H. L. Alling in this report.

TIME TABLE

Ordovician	Trenton	Cobourg limestone Canajoharie shale Addison shale Glens Falls limestone
	Black River	
	Chazy	Crown Point
	Beekmantown	Absent?
Cambrian	Monkton	

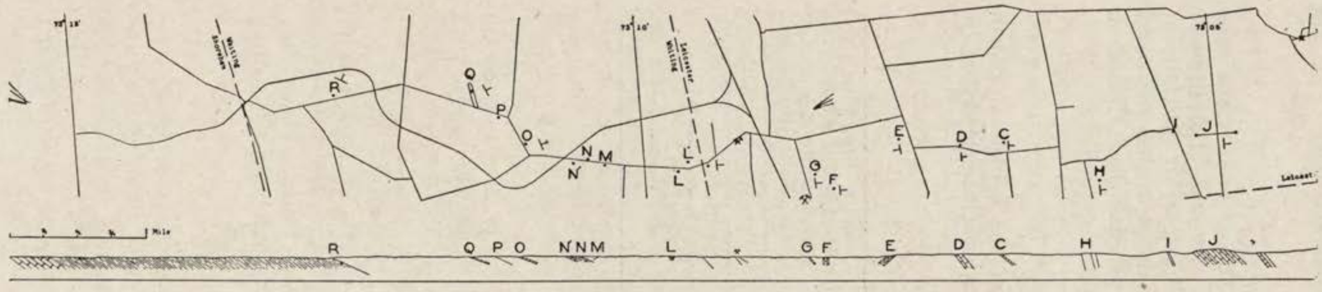

FIGURE 31.—Map and structure section based on a plane table traverse across Whiting and Leicester, Vt.

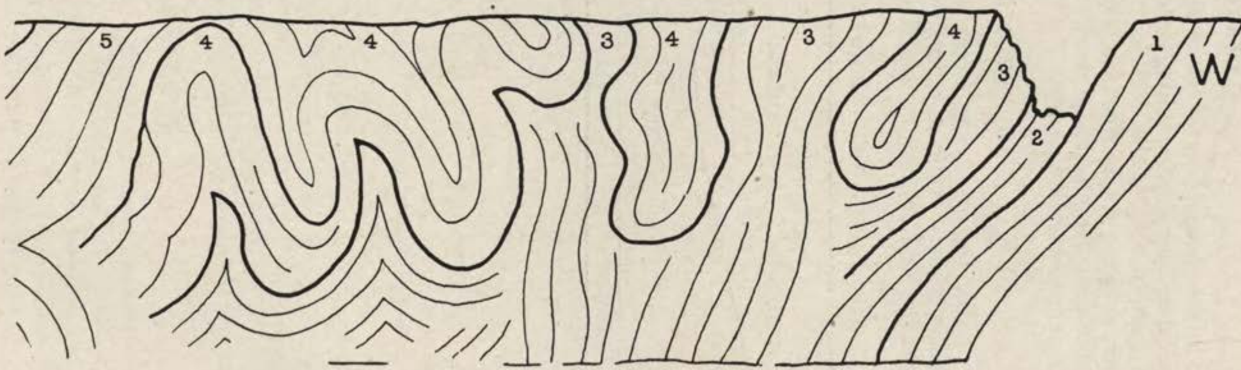

FIGURE 32.—Structure section, Huntley Quarry, Leicester Junction, Vt.

ROCK CORRELATION STUDIES IN WEST-CENTRAL VERMONT

EDWARD J. FOYLES

INTRODUCTION

The present paper is one of a series in which the writer is attempting to describe, correlate and map the geological formations of Vermont and townships bordering Lake Champlain. The work of mapping these townships has necessitated an excursion to the eastward to find the relationships of the Green Mountain rocks to those of the Vermont and Champlain Valleys. The localities encountered in this paper may be found on the Ticonderoga, Brandon, and Rochester topographic sheets published by the United States Geological Survey. The area may be reached conveniently from Brandon, Vermont, by automobile.

I wish to express my thanks to Professor H. L. Alling for his assistance in the study of the petrographic thin sections, and to Professor G. H. Perkins for his approval of this work. Professor C. H. Richardson has kindly cooperated in the compilation of the stratigraphic correlation table. Professor J. Edmund Woodman went over the ground with the writer and gave much help in interpreting stratigraphic relationships.

The field work was carried on in the summers of 1927 and 1928. A section was run from Larrabee Point on Lake Champlain to Rochester in the Green Mountains. The stratigraphy in the township of Shoreham, which is on the western end of this section, was not studied in great detail because it has been found that the work of Professors Brainard and Seeley as recorded was sufficient to determine the nature and thickness of the strata without making more than a cursory survey and collections from the different beds. In the western part of Whiting a plane table survey was begun which extended across Whiting, Leicester and Goshen (Figure 31). The line of section ran along the highways near the southern border of these townships. The horizontal and vertical position of every outcrop within the line of sight was recorded and mapped. Dip and strike were taken for each outcrop and specimens collected, in many cases over every foot of the outcropping surface. Where fossils were obtainable they were collected.

A supplementary section was run through Rutland and Mendon, and other shorter ones at Chittenden, North Clarendon and Arlington.

GENERAL RELATIONSHIPS OF ROCKS

STRUCTURE

The rocks across the section studied were found to be metamorphosed, faulted, and folded. In Shoreham the stress seems to have been severe. While the rocks are not extremely folded they are nevertheless greatly faulted and dip at sharp angles. In Leicester the effects of stress have been found in the unusually close folding of the beds as shown in the lime quarry at Leicester Junction (Figure 32). This stress would seem to be somewhat less across the eastern part of Leicester and Goshen and Rochester if the observance of surface conditions can be trusted; but the rocks, nevertheless, are nearly always dipping at angles averaging 45°. One of the most striking facts about the rocks is that they dip almost without exception to the east. Because of such deceiving surface conditions, it might be thought that the beds are of great thickness. However, the isoclinal folding, as shown in the quarry at Leicester Junction, indicates that the beds are only a third or a fourth the thickness as determined by surface measurements. The tendency to overestimate the thickness of the beds is a common error.

In general the rocks in Shoreham, Whiting, and Leicester are limestone and shales in great abundance, with a subordinate amount of sandstone. In Goshen and Rochester the rocks seem to consist of conglomerates, dolomites, phyllites, and schists. In the Shoreham rocks fossils are present which are easily identifiable. In Whiting fossils are rare and those found cannot be determined specifically. No fossils were found in the western and central part of Leicester, but a few Cambrian forms have been collected in the eastern part of the township. Fossils have not been found in Goshen or Rochester.

SPECIFIC DESCRIPTIONS OF THE ROCKS

Petrographic thin sections of the rocks of Shoreham have been described in a previous paper.[1] Beginning in Whiting we first encounter the Trenton limestone which is a blue gray rock in thick beds bearing fossils. The thickness is estimated to be 250 feet.

Trenton Shale—Canajoharie.—This is a black, fissile shale in which no fossils have been found. It contains chlorite, epidote, calcite, dolomite, chalcedony, carbon, sericite, and various colloids.

[1] Foyles, E. J., Rpt. Vermont State Geologist, 1923-1924, pp. 207-209.

It is quite sandy and slumping seems to have occurred before induration. The rock is taking on the characteristics of phyllite.

Station R.[1]—This rock is a black, fissile shale corresponding to the Canajoharie and is apparently at the eastern edge of that formation.

Station Q, *Trenton Limestone.*—This is a dark gray, thin bedded lime rock yielding obscure fossils. The outcrop is 45 feet in thickness.

Station P, *Trenton Limestone.*—This is a dark gray, platy, schistose lime rock.

Station O, *Trenton Limestone.*—This is a dark gray, platy, lime rock, 75 feet in thickness.

Station N, *Trenton Limestone.*—This is a dark gray, platy, crushed lime rock, 300 feet in thickness, which appears to have obscure fossils.

Station M, *Trenton Limestone.*—This is a blue gray, bedded lime rock whose thickness is undetermined.

Station L, *Chazy Limestone.*—This is a light gray, somewhat platy, fine grained lime rock, 45 feet in thickness.

"Roll" Quarry Limestone.—This is a black, platy, shaly limestone exhibiting slickensides and pyrite. A blue gray massive limestone shot with calcite, lies beneath the black platy limestone.

Leicester Junction Quarry.—The rocks of this quarry have been extremey folded as shown in Figure 32. Six beds can be be distinguished and their thickness approximately determined. Beginning at the top of the series we have bed No. 6, a dark gray, platy dolomite containing a small amount of pyrite. This is a muddy, carbonaceous rock 40 feet in thickness.

Bed No. 5 is a platy limestone with light gray and yellow laminae. It is 5 feet in thickness.

The lower part of bed No. 5 consists of 4½ feet of white and green beds of ophicalcite which is somewhat platy.

Bed No. 4 is a massive, blue-gray dolomite 10 feet thick.

Bed No. 3 is a platy limestone consisting of three parts. The uppermost shows yellow, pink and blue laminae; the middle part is composed of pink laminae and the lowest part is white with some serpentine. The whole is 12 feet thick.

Bed No. 2 is a massive gray limestone with brown banding, 10 feet thick.

Bed No. 1 is a massive light gray dolomite, 25 feet in thickness.

Station G is a dolomite schist 60 feet in thickness and consisting of two parts. The upper beds are light gray, platy, shim-

[1] The geographic positions of these stations are shown by corresponding letters on the map, Fig. 31.

mering, crumpled layers of striped appearance. The lower part is blue-gray and massive.

Station F is a massive dolomite with light and dark gray layers. The rocks of Station F are 210 feet thick.

Station E. Upper beds: Light and dark gray bands of crumpled shale and siliceous dolomite which are badly crushed. Middle part: A light gray limestone of micaceous layers. Lower part: Crumpled limestone and shale layers containing mica plates. The total thickness of the three layers is 240 feet.

Station D is a light gray and iron gray dolomite schist, consisting of crumpled and platy layers. This rock is 290 feet thick.

Station C is a massive dolomite consisting of light gray, blue gray, and iron gray layers 75 feet in thickness. This may belong to the Tribes Hill. Pseudo-phenocrysts somewhat grouped lie in a groundmass of fine-grained dolomite, quartz, and feldspar. Hematite is present. The transportational history is comparatively simple.

Stations H to I consist of quartzite interbedded with dolomite, 4,200 feet in thickness. The quartzite is light gray and brown in color and consists of thin and thick beds some of which are strongly pyritiferous. Other minerals are microcline in abundance, plagioclase, zircon, mica, and apatite. The dolomite is light gray and green, in thin and thick beds which do not seem to be strongly metamorphosed. Other minerals are pyrite, microcline, plagioclase, and quartz. The slide suggests an arkosic character of the rock.

Station J. *The Rutland Dolomite.*—This is a light brown and white rock 4,500 feet in thickness. It is somewhat siliceous and slightly recrystallized.

Cheshire Quartzite.—This rock occurs in light brown and gray massive beds bearing lower Cambrian fossils. It is 3,000 feet in thickness.

The Lana Conglomerate.—This rock consists of a quartz conglomerate with fragments of older rock in it. Metamorphism has reunited many of the pebbles.

The Lana Shale.—A phyllite with foliation doubtfully cutting across the bedding planes. The mica in it is badly altered and it contains plagioclase feldspars. The rock alternates with slaty-banded sandstone.

Mendon Dolomite.—This dolomite shows mica streaks, magnetite and pyrite.

Ripton Conglomerate.—This is a quartz mica schist showing pyrite in striking amounts, muscovite, microcline, and microperthite. In places the rock looks like an augen gneiss.

The last four beds mentioned are considered to be equivalent to the Mendon series of Whittle.[1] As a check on the section described in detail above, another section was run through the townships of Rutland and Mendon 25 miles to the south; and this section is here briefly described because of its value in comparison of the rocks which particularly concern this paper.

The marble belt, West Rutland, is thought to be in large part of Chazy age because of obscure Chazy fossils which have been found in it. On the eastern flank of Pine Hill at Rutland, we find a bedded quartzite which is light gray, brown, and a mottled gray-brown in appearance. The beds are separated by quartz schist layers, dark gray in color, which are laminated and yield pyrite, mica and possibly tourmaline. This quartzite is probably the Cheshire quartzite. East of this in the valley of the city of Rutland, we find the massive, light gray, Rutland dolomite which has yielded lower Cambrian fossils such as *Kutorgina cinculata* (Billings). On the eastern edge of the city is found quartzite interbedded with dolomite. In the town of Mendon we encounter the Cheshire quartzite which contains a small amount of mica. This quartzite has been seen in contact with the dolomite series. As we go up hill from this quartz we go down through the Mendon series, according to Whittle. The next outcrop to the east is a shaly limestone 800 feet in thickness. This is a very complex rock containing mica, calcite, dolomite, quartz, pyrrhotite, andesine, and various feldspars. The next outcrop is an impure quartzite 500 feet thick which has been injected by volcanic material. It contains biotite, muscovite, quartz, zircon, apatite, magnetite, hematite, and oligoclase. Going up higher we find 50 feet of the fine-grained dolomite marble known as the Mendon dolomite. It contains quartz grains. The highest outcrop reported is 350 feet of a green mica-quartz-actinolite schist. This rock is undoubtedly a sediment and may possibly have been injected by volcanic material. It is easy to conceive that it could have been derived from the Canajoharie shale.

When reviewing the Mendon series of Whittle in 1928 it was discovered that the Mendon dolomite in Whittle's type locality overlies, apparently conformably, the Cambrian quartzite which may be seen in the bed of the brook beside the dolomite outcrop. It was also noted that the Mendon series is overlain by a quartzite and that fossiliferous Cambrian quartzites and quartz conglomerate appear to lie along the east border of the lime rocks of the Vermont valley. Whereas the Mendon series as seen in Brandon is not strictly equivalent to the series in the town of Mendon, some doubt may be expressed that the two sec-

[1] Whittle, Journal of Geology, Vol. II, 1894, pp. 396-429.

tions are comparable as a series. Upon the basis of these meagre facts, the suggestion is offered that the Mendon series may be assigned at the present time to the Cambrian and that there is no Precambrian rock along the Green Mountain front.

RELATION OF FOSSILS TO PROGRESSIVE METAMORPHISM

Going eastward from Larrabee Point we find fossils abundant in the rocks on the lake shore, but less abundant in all other parts of Shoreham. In Whiting fossils are rare, and in Leicester fossils are rarely found, then only in the eastern part of the township. No fossils have been found in Goshen or Rochester.

The fossils found in Shoreham have previously been listed [in relation to their ages], and their notice here would be superfluous. The fact that they are abundant and in good condition is the important thing.

In Whiting, Station Q, fossils have been found. They are bryozoa and the eye of a trilobite, but the material is too poor for specific identification. One of the bryozoa has the vertical cross-section of *Prasopora*. The internal structure is indeterminable.

In the eastern part of Leicester fossils have been found in the past and were also collected by me from the lower Cambrian beds east of Fern Lake. The fossils are *Hyolithes communis* (Billings) and *Nothozoe vermontana* (Whitfield). These fossils consist of moulds, little or no organic material being left.

We may say in general that the fossils become obscure and finally disappear as we go eastward from Shoreham to Rochester. The non-fossiliferous area is strongly injected by igneous matters.

These conditions suggest several possibilities. The rocks may originally have had no fossils in them due to their extreme age in the pre-Cambrian, or it may have been that the seas were post-Cambrian but inhospitable to life. Any fossils in the sediments may have been destroyed by shearing processes or by recrystallization due to magmatic intrusion. The fossil evidence does not tell us definitely that the Mendon Series in Goshen and Rochester is or is not pre-Cambrian. The fossil evidence does permit us to assume that there is progressive metamorphism eastward.

RELATION OF IGNEOUS INTRUSION TO PROGRESSIVE METAMORPHISM

No marked evidence of igneous intrusion is noted in Shoreham, Whiting, or Leicester. In Goshen and Rochester, however, there is obvious indication of magmatic influence. In the schistose sediments we find tourmaline and feldspars in such relations to suggest that they have been injected and hence indicating proximity to a granite which indeed appears on the surface at the summit of Mt. Horrid. Stress and heat have influenced an advanced stage of metamorphism exhibiting biotite with quartz. Chlorite schists are abundant.

The facts indicate that igneous activity has had much to do with the metamorphism of the region. Consequently the sediments have been altered beyond recognition of their original state, and any evidence of former fossils has been obliterated. Any attempt to determine the age of the rocks must be based on superposition, stratigraphic continuity, or lithic characters. None of these being reliable in the present case, it is assumed that the age of the rocks is uncertain. We may conclude that there is a gradation from rocks somewhat metamorphosed by stress to rocks metamorphosed by stress, heat, and gases. In this region there is no evidence that the metamorphosed Mendon Series of this region is older than the rocks of the Vermont and Champlain Valleys. A study of thin sections reveals some evidence that the Mendon Series is part of the same series as the Vermont and Champlain Valley rocks and consequently not pre-Cambrian.

CONCLUSIONS

THE SHOREHAM-LEICESTER ROCKS

Upon the basis of the facts stated above we may assume that in these townships the stress was extreme, and that igneous activity was subdued, since few minerals are found in the rocks which are dependent upon such activity. The dikes and injections are irregularly dispersed at great distances from each other.

THE GOSHEN-ROCHESTER ROCKS

The rocks of these townships as well as the other townships studied have been subjected to pressure from the east at shallow depths. The pressure from the east is indicated in part by the steep western slopes of puckered laminae and in part by the topographic expression of the fault systems. Flattened and fractured feldspars indicate stress and heat. There is much crushing, granulating, and shearing; and the principal minerals found are chlorite, serpentine, talc, and hornblende. Upon these facts we may assume that the depth at which the pressure takes place was in the lowest part of the upper zone. We may furthermore conclude that the rocks have been subjected to acid igneous intrusions. The evidence of this is seen in the abundance of the mineral tourmaline which is thought to be dependent upon gas intrusion from acid magma. Feldspars indicate the proximity of granite, which is seen on the surface of Mt. Horrid and in

Mendon Village. A large quantity of biotite with quartz indicates an advanced stage of metamorphism, due to stress and heat. A combination of chlorite schists, quartz, muscovite, biotite, chlorite, magnetite, pyrite, and tourmaline indicate that thermal metamorphism has taken place in rocks which were mostly of fine and medium texture as indicated by their schistosity. As to the age of the Green Mountains in this part of the State, we may assume that they are very doubtfully of pre-Cambrian age as shown by the possible assignment of the Mendon Series to the Cambrian. It is quite probable that there are no pre-Cambrian rocks along the Green Mountain front.

We may readily conclude that these sediments with the central core of the Green Mountains are underlain by granite which lies at deeper and deeper levels as we go westward, under the Cambrian and Ordovician sediments which flank the Green Mountains.

The following tables indicate the present conception of the relationships of the rocks upon which this paper is based:

Correlation Table of Vermont Rocks

Arranged by E. J. Foyles and C. H. Richardson,
from original data and published works of Keith, Emerson, et al.

	Western Vermont	Central Vermont	Southern Vermont	Eastern Vermont
Quaternary	Pleistocene gravel, sand and clay			
Tertiary	Miocene, Brandon lignite			
Carboniferous		Diabase		Mt. Ascutney nordmarkite
Devonian	Dikes	Barre granite Bethel granite Calais granite Craftsbury granite Groton granite Hardwick granite Irasburg granite Newark granite Newport granite Orange granite Randolph granite Williamstown granite Woodbury granite		Pomfret granite Ryegate granite Tunbridge granite West Dummerston granite
Ordovician	Cobourg limestone(?) Canajoharie shale Addison shale Trenton limestone Glens Falls limestone Berkshire schist (in part) ——— Black River ——— Chazy { Valcour, Crown Point, Day Point } Columbian marble Sutherland Falls marble Berkshire schist (in part) ——— Beekmantown formation Tribes Hill dolomite Little Falls dolomite	Diorite, diabase Coventry limestone Orleans phyllite Bradford schist Vershire schist Waits River limestone Washington limestone Woodstock schist in Waits River limestone Randolph phyllite = Memphremagog slates Northfield slate Memphremagog slate Irasburg conglomerate	Bernardston formation Leyden argillite Conway schist Goshen schist Hawley schist Savoy schist Chester amphibolite Rowe schist Hoosac schist Berkshire schist Stockbridge limestone	Brattleboro phyllite Waterford slate
Upper Cambrian	Potsdam quartzite Georgia slate Swanton conglomerate Williston limestone Shelburne marble Highgate slate Milton dolomite	Gabbro, diorite Barnard gneiss Reading gneiss Missisquoi group Sericitic quartzite Sericitic schist Gassets schist Cavendish schist Bethel chlorite schist	Stockbridge limestone Halifax chlorite schist = Bethel schist Whitingham schist Heartwellville schist Readsboro schist	Lunenburg group Sericitic quartzite Sericite schist Chlorite schist Cavendish schist Newbury granite-gneiss Fairlee granite-gneiss Bellows Falls granite-gneiss
Lower Cambrian	Colchester dolomite Mallett dolomite Winooski marble Monkton quartzite Rutland dolomite Cheshire quartzite,	Ottauquechee formation Pinney Hollow schist Feldspathic quarzite Quartz-chlorite-mica schist Plymouth dolomite Sherburne conglomerate	Sherman marble = Plymouth marble Cheshire quartzite	
Pre-Cambrian			Stamford granite-gneiss	

CORRELATION OF ROCKS STUDIED IN THIS PAPER

Trenton	R Trenton shaly limestone Trenton limestone		
Black River	Q Fossils .... 45′ P .... O .... 75′ N .... 300′ L .... 45′	Dolomite .... 40′+ Calcite .... 5′ Ophicalcite .... 4½′ Blue Dolomite .... 10′ Calcite .... 12′ Calcite .... 10′ Calcite .... 25′+ G 60′ Striped schistose ls. Massive ls.	
Chazy		F 210′ { Ls. 200′ from base Ls. with dol. pebbles Limestone 160′	
Beekmantown		E 240′ Crumpled shale and limestone	
Tribes Hill		D 255′ Beekmantown =o= "Mendon" Dol.?	Mendon Series Green Mountain Gneiss
Little Falls		C 75′ Beekmantown (C. l.?)	
Cambrian (Potsdam)			
Lower Cambrian		H I Interbedded quartzite and dolomite .... 4,200′ J Rutland Dolomite .... 4,500′ K Cheshire Quartzite .... 3,000′ Fossils.	

A PORPHYRITIC MONZONITIC BOSTONITE

HAROLD L. ALLING

Through the kindness of Mr. Edward J. Foyles, I have had the opportunity of studying a specimen of a bostonite dike from North Ferrisburg. The dike is 30 feet wide and is seen cutting black Trenton shales for a distance of 40 feet. It is exposed 100 feet below bridge in what is locally called the "Hollow." In the hand specimen it is a porphyritic fine-grained yellowish brown rock, considerably weathered.

Under the microscope the phenocrysts appear to be zonally grown grains of oligoclase near Ab_{80} An_{20}. Rather refined optical determinations conclude that the composition of the plagioclase varies in composition, due to the zoning, from K-$Feld_5$ Na$Feld_{80}$ Ca-$Feld_{15}$ at the center to K-$Feld_4$ Na-$Feld_{85}$ Ca-$Feld_{11}$ at the margin. The plagioclase shows both albite and pericline twinning frequently in the same grain.

These are set in a fine-grained groundmass of soda-anorthoclase, soda microcline and anorthoclase grains, some of which exhibit microcline and cryptoperthitic structure. They are frequently zonally grown as well.

Interstially minute grains of quartz-feldspar intergrowths, or myrmekite aid in recognizing the cryptoperthitic character of the alkali feldspars. All ferromagnesian minerals are altered to secondary products, such as bastite, uralite, chlorite and carbonates. There is sufficient structure remaining, however, to suggest that both hornblende and biotite mica were primary minerals in the rock.

The striking porphyritic character of the rock, together with the composition of the plagioclase phenocrysts, shows that the term bostonite does not convey the proper conception of the rock. In reality it is, of course, akin to them in the alkaline character of the feldspars of the groundmass, its tachytic texture and paucity of ferromagnesian minerals. The small amount of quartz, even though intergrown with feldspar, the oligoclase phenocrysts associate the rock with the monzonites. The best name that can be proposed for it is *porphyritic monzonitic bostonite.*

Kemp and Marsters[1] state that in the bostonites from near Fort Cassin the "phenocrysts are in general not especially marked," while one "from the east side of Porter's Point, near Burlington,

[1] Kemp and Marsters, "Trap Dikes of Lake Champlain," U. S. Geol. Surv. Bull. 107, 1893, pp. 11-62.

consists almost entirely of large feldspar phenocrysts" "and in the great majority of cases [are] orthoclase." They further state that "a few well-authenticated plagioclases are recognizable." But it is not clear from their description whether they are referring to the phenocrysts or to the feldspars of the groundmass.

The interstitial quartz in the rocks here under discussion, I believe to be largely primary. This is indicated by the fact that many of such grains are intergrown with feldspar as myrmekite. Kemp and Marsters voice the opinion that in the usual bostonites some of the quartz may be secondary and perhaps all. They further state that they thought that the rock did not contain any recognizable dark silicate. The secondary products and iron stains they held to be infiltrations. The presence of the secondary carbonate they thought was due to introduced lime. While it is true that some of the chemical analyses included in their paper show a low lime content, as low as 0.45 per cent., yet the majority show a great deal more. The lime can be very well a part of the feldspar in the form of anorthite component.

In the North Ferrisburg dike the quartz is believed to be primary and the rock contained a small percentage of mica and perhaps hornblende.

It would appear that this dike represents a type of rock not so far noted in this region.

PRELIMINARY REPORT ON THE PENEPLANES[1] OF THE TACONIC MOUNTAINS OF VERMONT

ADELA MORSE POND

ADVANCED SUMMARY

The topography of the Taconic Mountains of Vermont has been studied by the author both in the field and by a series of projected profiles. The upland is found to consist of a series of terraces which decrease from a 3,200 foot elevation on the crest of the range successively to 2,700(?), 2,500, 2,000, 1,700, 1,300, 1,100, 900 and 700 foot elevations. These terraces were examined in consideration of both Davis' theory of the New England peneplane and Barrell's theory of terraces of marine abrasion. Throughout the region the terraces are found at elevations corresponding to those described by Barrell, but with progressive decreases in elevation toward the east, west, south, and north. No evidence, however, to point toward a marine origin was observed. Each terrace of the series remains near the same elevation throughout the region as well as in the southern New England area investigated by Barrell. This consistency in elevation disproves the existence of a southeasterly tilted peneplane and indicates a vertical movement during successive uplifts. The arrangement of the terraces points to a base level of erosion since at least as early as the formation of the 2,700(?) foot level in the Champlain-Hudson valleys, the northern part of the Vermont valley, and toward the south in Massachusetts. If an initial extensively developed peneplane existed into which these terraces were cut this region does not furnish sufficient evidence of it. Neither the 3,200 foot terrace nor the few areas of higher elevation furnish sufficient evidence to warrant any assumption as to the character of the land surface existing just prior to the formation of these terraces.

PREVIOUS INVESTIGATION OF PENEPLANES

In Europe the earliest investigators regarded the peneplane as a product of marine abrasion. Ramsay in 1846 was the first

[1] In this article I follow Dr. Douglas W. Johnson in his usage and spelling of the term peneplane to denote a nearly plane surface produced by erosive agents regardless of rock structure; and of plane to denote the level of erosion produced at the end of any cycle (25).

to publish the belief that extensive planes had been produced by marine erosion and to such a plane he gave the name, plane of submarine denudation (31).

In America such planes were regarded as the product of subærial erosion. Following the explorations of the Colorado River, Powell, in 1875, called attention to a vast plane of denudation produced by subærial erosion (30). Seven years later Dutton, considering the history of the Grand Canyon, also asserts his belief in planation by subærial erosion (18). Gilbert, although expressing his belief in this trend of subærial forces, limits its efficaciousness in that "in reality it (the law of uniformity of slope) is never free to work out its full results, for it demands a uniformity of conditions which nowhere exists" (22, p. 115).

The more detailed determination of such planes was commenced in 1889 in the eastern United States. During that year William Morris Davis found evidence of two such denuded planes in Pennsylvania (the Schooley and the Somerville) to which he assigned the dates, Jura-Cretaceous and Tertiary, and the names, Cretaceous and Tertiary base level lowlands. With the Cretaceous level he associated "the extraordinarily persistent accordance among the crest-line altitudes of many Medina and Carboniferous ridges in the central district (Penn.), the general corresponding elevation of the western plateau's surface * * * the general uniform and consistent altitude of the uplands in the crystalline highlands of northern New Jersey and the south mountains of Pennsylvania, and the extension of the general surface descending slowly eastward, over the even crests of the Newark trap ridges" (10). In this grouping we find for the first time the idea of tilting toward the southeast accompanying the uplift. Davis also states it more definitely. "The broad lowland is no longer. It has been raised over the greater part of the area into a highland, with an elevation of from one to three thousand feet, sloping gently eastward and descending under the Atlantic level near the present margin of the Cretaceous formation" (10). From this time up to the present tilting toward the southeast has been considered a factor accompanying the uplift of the Cretaceous peneplane. Later in the same year, while describing the restored form of the Connecticut upland, Davis named such a plane a *peneplane* (11). In 1890 he asserts the peneplane to be of subærial origin for the reason that there are no Triassic fragments in the overlying Cretaceous sediments which would be found if of marine origin (12). The year following the completion of the New Jersey peneplane is placed in the Cretaceous since the crest line of the Triassic lavas goes beneath the oldest of the Cretaceous beds (13).

Davis investigated the subject in southern New England, in 1895, and came to the conclusion that "Southern New England for the most part is a slanting upland reaching elevations of from 500 to 2,000 feet in Vermont and western New Hampshire near the Massachusetts line, and descending gradually to the coast on east and south" (14, p. 269). He considered the Green and the White Mountains to be probably of monadnock character.

A peneplane (the Harrisburg) between the two determined by Davis in Pennsylvania was recognized by Campbell in 1903 (7), and from that time until Barrell's re-examination of the subject the majority of investigators explained the physiography of the eastern United States as due to three prolonged cycles of subærial denudation, although Arthur Keith had cited evidence of five cycles in the Appalachians of Maryland and Virginia as early as 1894 (26) and later had expressed his opinion that the topography of the southern Appalachians was the result of erosion in numerous cycles (27).

A re-examination of the character of the New England peneplane was made by Joseph Barrell during 1909 and 1910. The rise was discovered to consist of a series of horizontal benches and to these a marine origin was ascribed (2). Barrell and in 1921 Bascom (6) cite the area between the Appalachian Valley and the Coastal Plain as one in which numerous interrupted cycles have played the major rôle in producing its topography.

The investigation of the subject in New England has so far been restricted to the lowlands, with the exception of the White Mountains into which Lobeck, in 1917, traced the New England peneplane in accordance with the character conceived for it by Davis (29).

This article deals with the investigation of the subject in the Taconic Mountains of Vermont. In it I subscribe to numerous interrupted cycles of subærial erosion with vertical uplift inaugurating each new cycle, producing terraces such as those described by Barrell. A discussion of a subærial versus a marine origin for the terraces is given by Professor H. A. Meyerhoff whose report on "The Erosional Land Forms of Eastern and Central Vermont" appears in this issue, and with whose views I am in accord.

ACKNOWLEDGMENTS

Opportunity is here taken to express my appreciation of the assistance received in the preparation of this report. Professor Douglas W. Johnson, of Columbia University, has been ever ready to aid me. It was in his class room that the problem was first suggested as a part of a study of peneplanes by projected profiles

begun at Columbia several years ago; and it has been due to his encouragement that a solution has been attempted. Circumstances have compelled the author to prepare this report for publication during Professor Johnson's absence and without opportunity to confer with him in the field or to discuss the conclusions reached in this report. Professor Howard A. Meyerhoff of Smith College has studied the same problem in the Green Mountains of Vermont and has freely discussed with me the results of his investigation and their significance.

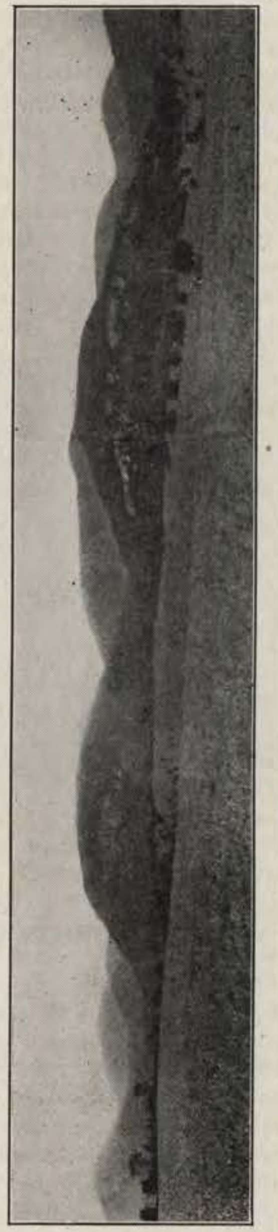

FIGURE 33.—Section of Taconic Mountains looking east from south of Lake St. Catherine. The terraces here fall toward the Champlain-Hudson Valleys. The prominent front range is at the elevation of 1,300 feet. The higher range back is 2,000 feet.

THE PROBLEM

The problem before us is to examine the erosion levels of the Taconic Mountains and correlate them with those already determined in other areas; and to consider the mode of formation of these various levels—that is to consider whether they are products of a few long periods of subærial denudation interspersed with uplift and tilting toward the southeast, as Davis considers the levels of Massachusetts, Connecticut, and Rhode Island and Hayes and Campbell regard the levels of the southern Appalachians; or whether they are products of numerous relatively short periods as Knoff, Bascom and Barrell consider those of the northern Appalachians; or whether they represent numerous platforms of marine abrasion as Barrell holds for those levels which constitute the New England peneplane.

The approach to the problem of the physiography of the

Taconic Mountains consists of field observations of the entire region made in connection with the study of a series of projected profiles.[1] These profile projections cover an area approximately twelve miles east by west and ninety-five miles north by south. The area extends from the region of the New England peneplane in northwestern Massachusetts northward to the Champlain lowland. It is covered by six of the United States Survey topographic sheets—from south to north the Greylock sheet in Massachusetts, and the Bennington, Equinox, Pawlet, Castleton and Brandon sheets in Vermont. The area was divided into three-mile sections extending twelve miles east by west. A generalized profile extending east by west was made for each section by plotting the highest point every one-tenth of a mile (see Figures 38 to 43). A three-mile section was found to be more advantageous than a broader one, on account of the great variation of levels in this region. Several broader sections were tried with the result that the higher levels were so dominant as to nearly obliterate the lower levels in the resulting profiles. The east by west sections were found to be of greater diagrammatic value than the north by south sections on account of the general north-south trend of the terraces, parallel to the mountain axis. This trend causes the majority of generalized profiles of north-south sections to fail to adequately portray the distribution of the terraces. The highest points taken for the projections of these profiles will be either on the higher terrace levels with the result that the lower terraces are completely concealed in the resulting profile; or often the points of projection will be points consecutively at the same elevation on an intermediate slope with the result that a level appears in the profile where actually none exists. A vertical scale of 1,000 feet to the inch was chosen in preference to a larger scale as the great relief, the degree of dissection, and the narrow extent of the levels make impractical an adequate pictorial presentation by a larger scale.

DESCRIPTION OF THE TOPOGRAPHY

The result of this study is to discover that the topography of the Taconic Mountains resolves itself into a series of terraces at very definite elevations (see Figures 38 to 43). The topography of the entire range is dependent upon the arrangement of these terraces over a frame work of structural topography. The Taconic Mountains extend from Sudbury, Vermont, near the Rutland-Addison County boundary line southward into northwestern Massachusetts and eastern New York. Physiographic-

[1] These profiles were projected by the system of multiple projected profiles devised at Columbia for the study of peneplane surfaces.

ally our area of the Taconic Mountain is bounded on the north by the Champlain lowland; on the east by the Vermont Valley; on the west by the Champlain-Hudson valleys. On the south the mountains extend into Massachusetts and New York. Structurally the mountains are a great synclinorium; topographically a series of rock terraces superposed upon a general plan of anticlinal and synclinal valleys and mountains, with north-south strike. The north-south trend of the topography is interrupted by five transverse valleys. Along these valleys the series of terrace levels deviate from their north-south trend and finger upstream. These transverse valleys are those of the Hoosic in Pownal, Petersburg and Hoosic; the Mettawee in Pawlet, Rupert

FIGURE 34.—Dorset Mountain looking above the Vermont Valley from South Wallingford. The terrace at the left of the summit is the Dorset Terrace 3,200 feet elevation.

and Dorset; the Walloomsac in Bennington and Hoosic; the Battenkill in Arlington; and the Castleton in Castleton and West Rutland. The streams flow west. All but the valley of the Mettawee are as low as 800 feet or lower, and in half of its course it is 800 feet or lower. The major longitudinal valley of the region is the Vermont Valley, which separates the Green Mountains from the Taconics, and which is often classified with the Taconics. North of Dorset it is divided into two longitudinal valleys bounding a line of hills between 1,200 and 2,000 feet in elevation; south of Dorset it continues a regular course to near the Massachusetts line where it is interrupted by the junction of Mount Anthony to the Green Mountains. From Pittsford to West Rutland there is a short, but conspicuous longitudinal valley, the West Rutland

Marble Valley. The crest of the range is well toward the east of the mountain area. Where it attains its maximum height, in the mid north-south section, it ascends abruptly from the Vermont Valley. The abruptness is caused by the incomplete development of the terraces at that point. The longer western slope of the mountains is characterized by broader terrace platforms.

These terraces appear at, or very nearly at, the elevations of 3,200, 2,700(?), 2,500, 2,000, 1,700, 1,300, 1,100, 900+ and 700+ feet. There is some doubt as to whether the 2,700 (?) foot level is an individual terrace or a variant of the 2,500 foot terrace, and is included in the series with that possibility in mind. Doubt arises from the fact that this level is not observed to occur immediately between the 3,200 and the 2,500 foot terraces as would be expected for an individual terrace, and yet, it occurs enough times at a uniform elevation and near either the 2,500 or the 3,200 foot terrace so as to demand investigation in other regions before the matter is decided.

FIGURE 35.—Taconics at South Wallingford. The two terraces are 2,000 feet and 2,500 foot terraces.

From the crest of the range the terraces descend toward three general areas; southward toward the area of the New England peneplane, westward toward the Champlain-Hudson Valleys, and northward and eastward toward the Champlain lowland and its southern extension into the Vermont Valley as far as Wallingford. The lower levels are conspicuously absent or incomplete in development along the west wall of the Vermont valley from Wallingford south to Bennington. It is in this area that the

highest of the terraces and the greatest elevation and relief of the Taconic Mountains occur.

The 3,200 foot terrace forms the summit of Bear Mountain in Rupert, Dorset, Sandgate, and Manchester; of Green Peak of Dorset; of Spruce Peak in Bennington; and occurs as spurs on the south and east of Mount Equinox in Manchester and on the north and south of Dorset Mountain in Dorset. On Dorset Mountain it is represented by a fine wind-gap. The 3,200 foot level is seen to the best advantage upon Dorset Mountain and Mount Equinox where it occurs as high wooded platforms or shoulders. An excellent view of all but the western side of Dorset Mountain is obtained from the Vermont Valley. The level appears as a distinct platform a little below and east of the summit. The best view is had from South Wallingford, Vermont, looking south along the Vermont Valley (see Figure 35). From this site it is conspicuous in contrast to the long steep, regular incline of the northern slope of the mountain which rises like the side of a pyramid out of the valley. Mount Equinox is also conspicuous above the valley, but the best view of it for our purposes is to be had from the abandoned quarry on the southern slope of Dorset Mountain. Southwest from the quarry Mount Equinox is seen rising majestically, the highest of the Taconics. High up, a long wooded spur extends northeast toward Dorset Mountain. This is the 3,200 foot terrace. Looking south down the Vermont Valley, we see at its farther end Mount Anthony whose elevation

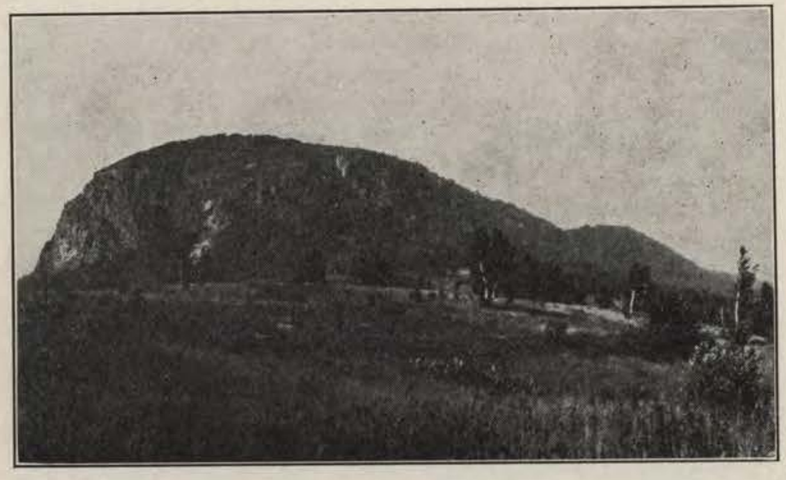

FIGURE 36.—Bird Mountain. The elevation in the foreground 1,600-1,700 feet (1,700 foot terrace). Summit 2,200 feet (2,000 foot terrace).

is 2,345. Many points of interest upon the Green Mountains also appear from here.

The 2,700(?) foot terrace occurs as the summit of Red Mountain and The Ball in the township of Bennington, on Burnt Hill in Rupert township, Netop Mountain in Dorset, Tinmouth Mountain in Tinmouth, and Herrick Mountain in Ira township. It occurs as a spur on the south of Dorset Mountain. In the field the 2,700 foot terrace is not distinguishable from the 2,500 foot terrace. Its character as an individual terrace would not be surmised except for a study of the topographic maps and the profiles. It occurs on but a few high mountain tops. The change in slope on the southern spur of Woodlawn Mountain strongly suggests its character as an individual terrace between the 3,200 foot and 2,500 foot terraces. An excellent view of the 2,700 foot level on Herrick Mountain and of the levels lower than the 2,700 foot is obtained from Bird Mountain, in the townships of Ira and Castleton. Bird Mountain has an elevation of only 2,200 feet. An extensive view, however, may be had from its summit. On the south of Bird Mountain is a great cliff which falls to an area of rolling meadow land between 1,600 feet and 1,700 feet (see Figure 36). From the summit Herrick Mountain is seen directly southeast across the valley. The elevation of Herrick Mountain is 2,727 feet. The mountain directly east across the valley presents the 2,000 foot terrace and the accordance of summit level between it and Bird Mountain is at once apparent. Farther toward the east are the Green Mountains. Northwestward is seen lower land in which the 1,100, 900+, 700+ foot levels predominate. The view extends to Lake Champlain and the Adirondacks. Southwest is seen Lake Saint Catherine and clustered about it many hills of 1,300 foot elevation.

The 2,000, 1,700, 1,300 foot terraces can be well observed from the vicinity of Lake Saint Catherine. East of the Lake the 1,300 foot level is prominent on the summits of a long north-south line of mountains with bold western escarpments. Glacial scouring, which has removed all traces of the 1,100 foot terrace, probably caused this western accentuation of slope. Just east of these mountains is a higher line with summits of 1,700 and 2,000 foot elevation (Figure 34). Farther east of this area, at Danby Four Corners, the 1,300 foot level, for two miles north and south of the corners, appears as a flat valley floor. It abuts sharply against the mountains which close the valley on the south. To the north it has been cut into by Tinmouth channel. A wind gap at 1,300 foot elevation cuts through Tinmouth Mountain, showing that probably the drainage of this valley at some time during

the formation of the 1,300 foot level was westward through the Poultney river. The southern part of the valley now drains eastward by way of a post glacial gorge into the Vermont Valley. It is here interesting to note that as a rule the cols through which the majority of roads pass over the divides are wind gaps at the level of one of the terraces.

Another excellent locality for observation of the 2,000, 1,700, and 1,300 foot terraces is along the main road several miles south of Brandon. The mountain range rises abruptly from the southern extension of the Champlain lowland and is silhouetted against the sky so as to make the individual terraces very distinct in outline (Figure 37).

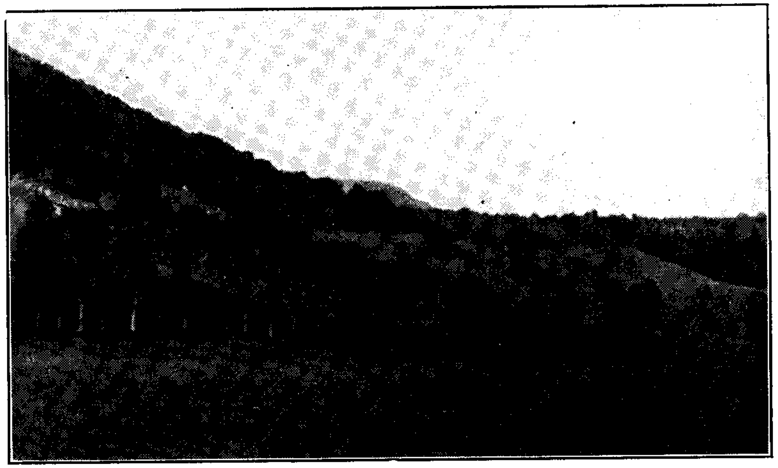

FIGURE 37.—The Metawee Valley at Dorset. The 700+ foot terrace is seen on the left of the valley.

The 900+ and 700+ terraces are not as extensive or as clearly shown as the higher terraces. These two terraces appear along all the larger streams. In many instances glacial drift so covers them as to cause them to appear as kame terraces, however, frequent rock outcrops at 900+ and 700+ give evidence of them. In the northwestern section of the Taconics these terraces and the 1,100 foot terraces are particularly well developed. An excellent view of this section is obtained from Bird Mountain, previously mentioned. However these terraces are seen to the best advantage at close range. A drive along any of the valleys in the townships of Castleton and Hubbardton will well repay in observations of these terraces.

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Another excellent locality for observation of the 2,000, 1,700, and 1,300 foot terraces is along the main road several miles south of Brandon. The mountain range rises abruptly from the southern extension of the Champlain lowland and is silhouetted against the sky so as to make the individual terraces very distinct in outline (Figure 37).

FIGURE 37.—The Metawee Valley at Dorset. The 700+ foot terrace is seen on the left of the valley.

The 900+ and 700+ terraces are not as extensive or as clearly shown as the higher terraces. These two terraces appear along all the larger streams. In many instances glacial drift so covers them as to cause them to appear as kame terraces, however, frequent rock outcrops at 900+ and 700+ give evidence of them. In the northwestern section of the Taconics these terraces and the 1,100 foot terraces are particularly well developed. An excellent view of this section is obtained from Bird Mountain, previously mentioned. However these terraces are seen to the best advantage at close range. A drive along any of the valleys in the townships of Castleton and Hubbardton will well repay in observations of these terraces.

SIGNIFICANCE OF THE TOPOGRAPHY

Let us first examine the topography of the Taconic area in view of Davis' New England peneplane. In this, frequent consultation of the topographic maps of the region will be of utmost value. On the Hawley sheet of northwestern Massachusetts the recognized elevation of the New England peneplane is 1,700 feet which it was believed was attained by a uniform rise from the southeast. Following this northward inclination into Vermont, into the area of the Taconics, we would expect to find the levels arranged either successively higher to extend the inclination of the southeasterly tilted peneplane, or arranged to show warping faulting, or some other deformation of the peneplane surface. At first it appears as if the tilting extended into the area of the Taconics for in the southern part of the area there are two new levels at 2,000, and 2,500 foot elevations. Tracing the extension of the New England peneplane throughout the area, however, it is found that this level of 2,500 feet continues through to the northern end of the range with only a few peaks of higher elevation rising monadnock fashion above it. At the northern end of the range it ceases and the elevation in the short space of ten miles decreasing successively to 2,000, 1,700, 1,300, 1,100, 900+, 700+, and 500 foot elevation, the level of the Champlain lowland. The question arises whether the New England peneplane is so warped or faulted as to account for these lower levels. There is no stratigraphic evidence to bear this out. It is to be noted that Bain in 1927 located the New England peneplane at 1,850 in this area near Brandon and at 2,500 upon the Green Mountains east of Dorset (1).

Examining the western slope of the Taconics we find that the upland continues at 2,500 feet for several miles beyond the ridge of the mountains. The elevation of the mountains then terrace-like decreases toward the Champlain-Hudson valleys to successive levels of 2,000, 1,700, 1,300, 1,100, and 900+ and 700+ feet. Again the question arises whether deformation can account for this. An examination of the profiles and the topographic maps of the area answers that question for us. From the profiles we see that there is a repetition of levels throughout the area and that each individual level, or terrace, is found at the *same average elevation throughout the entire region.* Consulting the topographic maps for a more thorough understanding of the relation of these terraces to the topography of the region, we find that these terraces are not restricted to zones in a manner which would accord with a deformed peneplane surface, but, forming a dendritic pattern, follow up the valleys of the larger streams. We also find that the lower levels found farther to the south and

there considered as tilted remnants of the New England peneplane do not disappear in the area of the Taconic Mountains, and moreover, in many cases can be traced from one region to another and shown to be co-extensive.

These levels although they are found more abundantly south of Vermont and in the area of the Champlain-Hudson valleys do not, however, disappear in the regions where the higher levels dominate, but, fingering up the valleys of the main streams, do continue. These facts compel the conclusion that the several levels do not represent a single peneplane deformed during uplift, but are the result of numerous relatively short periods of denudation.

Let us now turn to Barrel's theory of marine terraces. During 1909-1910 Barrell re-examined the character of the New England upland and discovered the rise to be in a series of horizontal terraces. In 1912 he traced these terraces from Mount Greylock southward to Long Island Sound. These he gave as follows (5):

Becket	2,450 foot elevation
Canaan	2,000 foot elevation
Cornwall	1,720 foot elevation
Goshen	1,380 foot elevation
Litchfield	1,140 foot elevation
Prospect	920 foot elevation
Towantic	740 foot elevation
Appomattox	540 foot elevation
New Canaan	400 foot elevation
Sunderland	240 foot elevation
Wicimico	120 foot elevation

Professor Barrell traced the inner margin of the Becket terrace across the southern slope of Mount Greylock and northward into the Green Mountain area. He considered this to define the shore of the Cretaceous sea. The most clearly marked of the terraces are those south of the Cornwall. It is these terraces which led Professor Barrell to consider the series to be of marine origin.

Comparing Barrell's series with that series of terraces found to constitute the topography of the Taconic Mountains the correlation is at once apparent. The Becket, Canaan, Cornwall, Goshen, and Litchfield terraces are well represented. These were traced from the position determined for them by Barrell on Mount Greylock northward into the Taconic area. The Prospect and Towantic terraces, however, are less clearly shown, and are often covered by glacial veneer so as to cause these two terraces sometimes to appear as one, and to often cause the Towantic terrace to appear as an 800 foot level.

One and possibly two terraces higher than those determined by Barrell occur in the Taconic Mountains in Vermont; one definitely shown at 3,200 feet and one questionably at 2,700. The terrace at the elevation of 3,200 feet is well developed upon Dorset Mountain which has at that elevation an excellent wind gap. The 3,200 foot terrace is named the Dorset terrace. Proof of a 2,700 foot terrace rests in some other area where its character as an individual terrace, or as a modification of the 2,500 foot terrace, can be better shown. Since the name should be taken from a type locality a name will not be ascribed here. We have then in the Taconic Mountains of Vermont the following terraces:

Dorset	3,200	foot elevation
?	2,700(?)	foot elevation
Becket	2,500	foot elevation
Canaan	2,500	foot elevation
Cornwall	1,700	foot elevation
Goshen	1,300	foot elevation
Litchfield	1,100	foot elevation
Prospect	900+	foot elevation
Towantic	700+	foot elevation[1]

That these terraces are independent of the rock structure is shown again and again. One of the best localities in which to demonstrate this is the Brandon area. Here the three important formations of the Taconics meet within a few miles and the five lower terraces determined for the Taconic Mountains appear without any dependence upon the formations.

There are two areas of particular value in studying the forces determining the topography of the area. Within a small radius each shows the majority of the topographic terraces and principal rock formations of the Taconics. They are situated at the extremes of the region under discussion and near separate localities of the sea as base level. One is the Brandon area; previously mentioned, at the extreme northern end of Taconics; the other the Mount Greylock area in northwestern Massachusetts. The latter forms an important topographic link between the New England upland in Massachusetts and both the Green and the Taconic Mountains of Vermont. Comparing the topography of the two regions we have the following terraces:

TERRACE ELEVATION

Mount Greylock	Brandon
3,200 feet	.....
2,500 feet	.....
2,000 feet	2,000 feet
1,700 feet	1,700 feet
1,300 feet	1,300 feet
1,100 feet	1,100 feet
900+ feet	900+ feet
700+ feet	700+ feet

[1] It is to be remembered that the position in relation to the divides during the formation of these terraces and erosion subsequent to their formation do not allow these terraces to appear exactly at these elevations in every case. These figures represent the best average elevations taken from the profile and map study.

Except for the 3,200 foot terrace these terraces are the same as those which Barrell considers to fall to the south forming the component parts of the tilted New England peneplane. They are also the same as those which are arranged dendritically along the major streams in the Taconic area. From this arrangement it is evident that the topography is due to erosion in numerous interrupted cycles, and that the movement during the uplift was vertical.

Judging by the systematic and uninterrupted declivity of the terraces from the Taconics southward down the New England peneplane to the Atlantic it seems apparent that the southern base level for the entire series of these terraces has been the Atlantic. The equality in elevation between these terraces which have their base level towards the south and those which have their base level towards the west and north indicates base levels of equal elevation, which in turn indicates an arm of the sea in the Champlain-Hudson valleys and the existence of the Champlain sea during the formation of the series.

The character of the land surface upon which these terraces were cut is a matter of conjecture as there is not sufficient evidence in this region to form a theory. The 3,200 foot terrace found along the crest of the mountains fails to show a definite relation to any base level. Moreover it is too sparsely developed to permit the assumption, generally made, that the pre-existing land surface upon which these terraces were formed was a penelane of vast extent. Nor are the few remnants which rise above the 3,200 foot terrace sufficient to suggest a pre-existing unpeneplaned land surface. The determination of the character of this land surface may, however, be found in regions of higher altitude and in the study of stratigraphy.

The presence of wind gaps in this region indicates that subærial erosion was at least a concomitant agent in the formation of these terraces. There is no positive evidence of marine origin. Moreover, the arrangement of the terraces in locations unfavorable to exposure to wave erosion tends to indicate that they are not of marine origin. In many instances, however, the terraces are developed more fully along the western flank of the mountains where, on account of prevailing westerlies, if the terraces were of marine origin, the fullest development would be expected. But, on the other hand, a well developed terrace at 2,000 feet is observed on the northeast flank of Mount Greylock which, on account of the nearness of the Green Mountains and the Hoosac Range would have been an especially sheltered locality; and yet again, in many instances, the terraces are well developed in what would at that time have been narrow estuaries.

SUMMARY CONCLUSION

The erosion levels of the Taconic Mountains of Vermont have been found to represent numerous interrupted cycles of erosion interspersed with periods of vertical uplift. The terraces are similar in appearance and elevation to Barrell's terraces of marine abrasion, and are correlated and often found to be co-extensive with the terraces determined by Barrell in Massachusetts. Their arrangement and general character, however, indicate a subærial origin rather than a marine.

Figures 38-43 are the generalized east-west profiles projected every three miles from the Champlain Lowland southward to the New England Peneplane in northwestern Massachusetts.

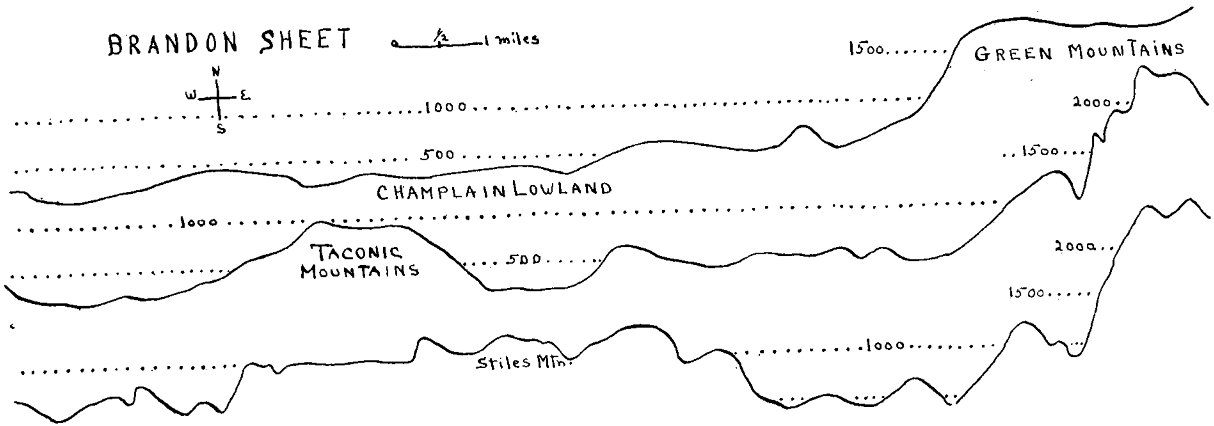

FIGURE 38.—Generalized east-west profile of the Brandon Topographic Sheet.

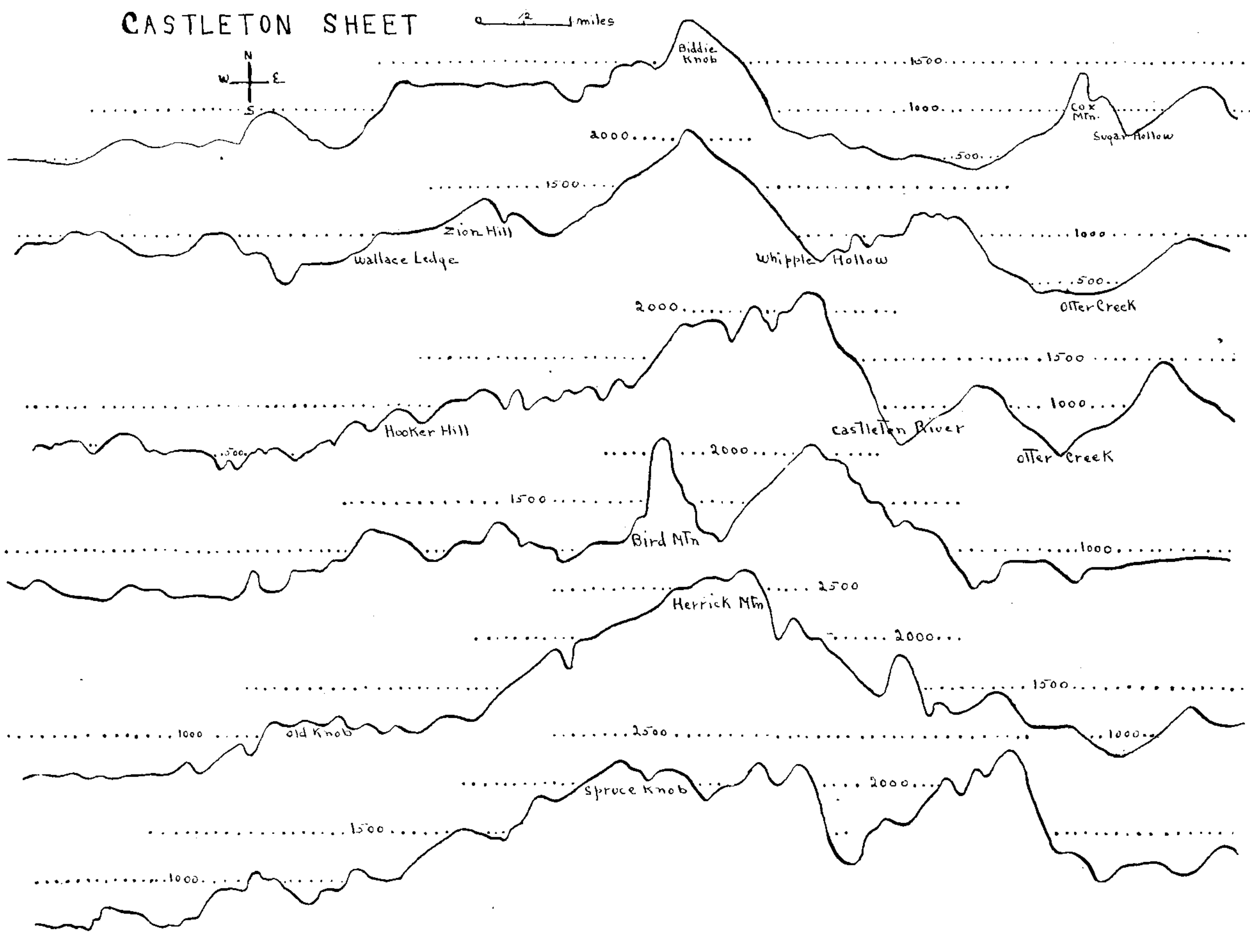

FIGURE 39.—Generalized east-west profile of the Castleton Sheet.

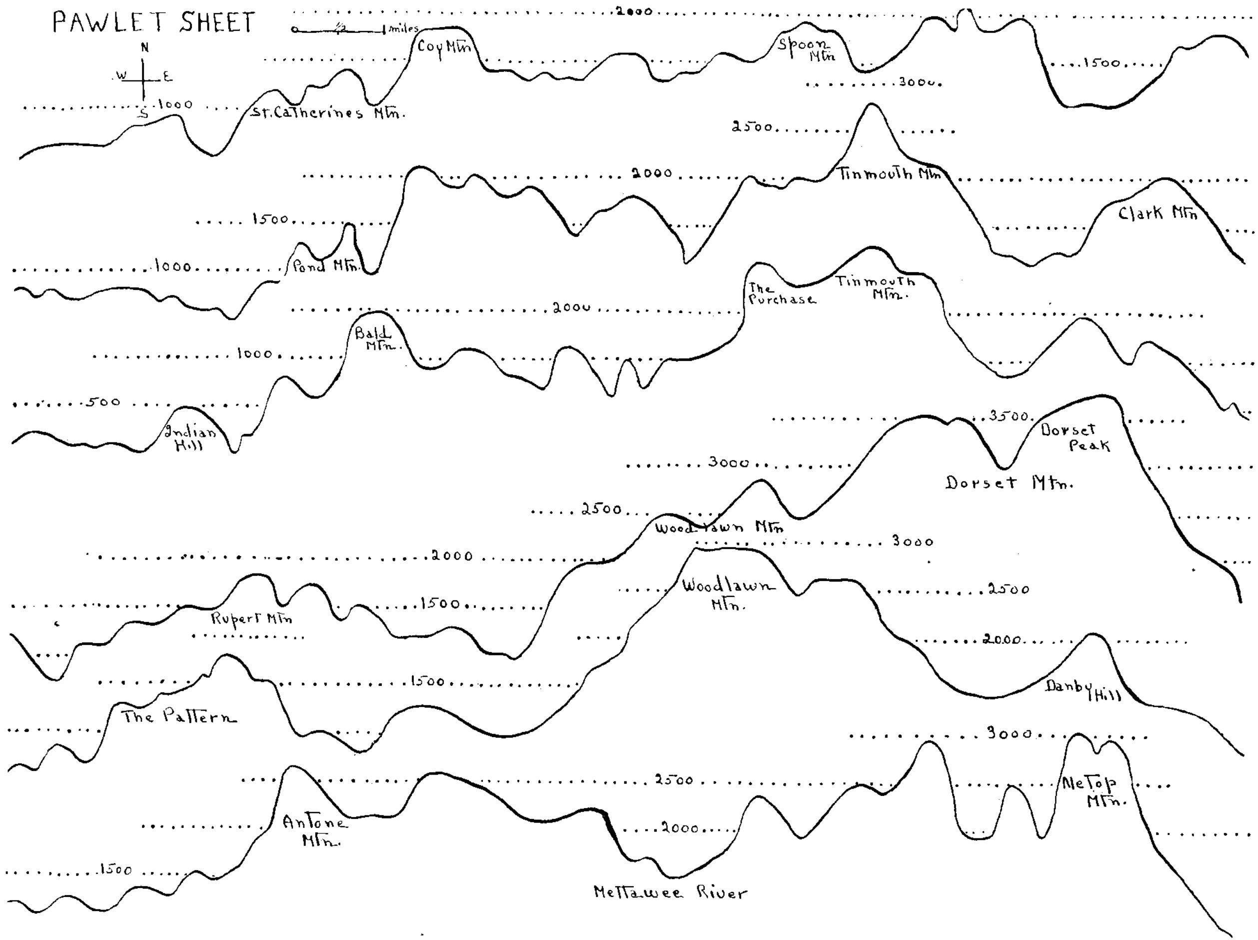

FIGURE 40.—Generalized east-west profile of the Pawlet Sheet.

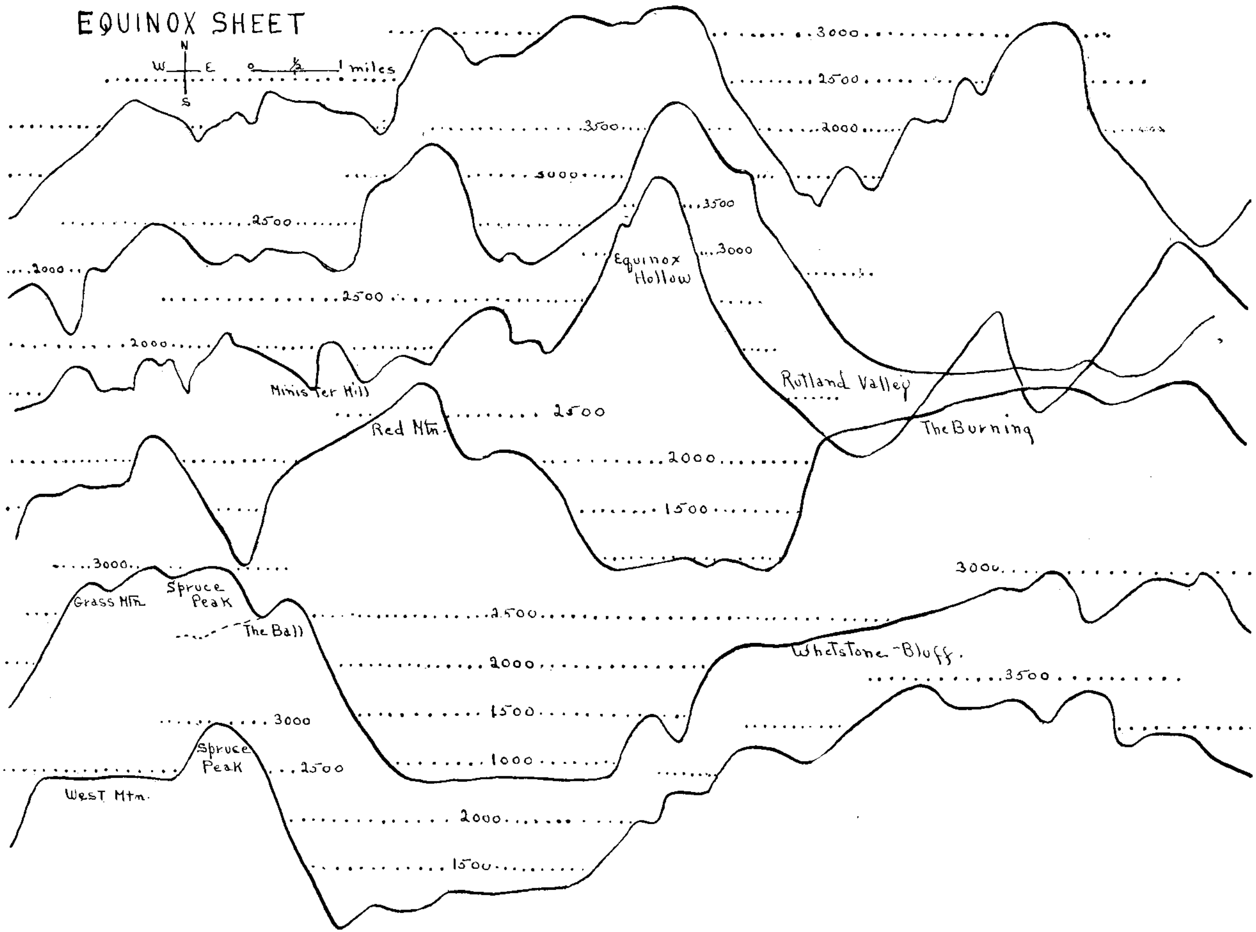

FIGURE 41.—Generalized east-west profile of the Equinox Sheet.

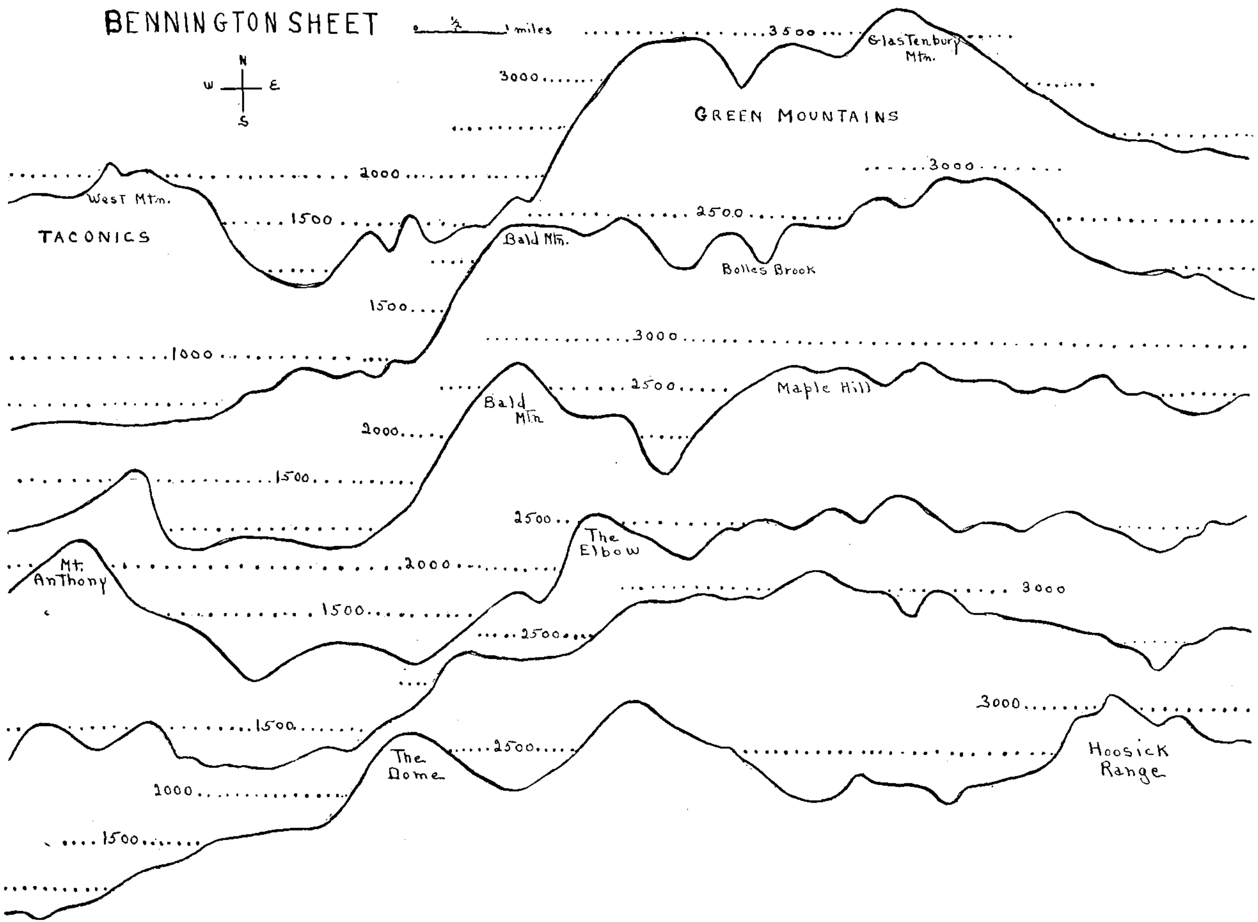

FIGURE 42.—Generalized east-west profile of the Bennington Sheet.

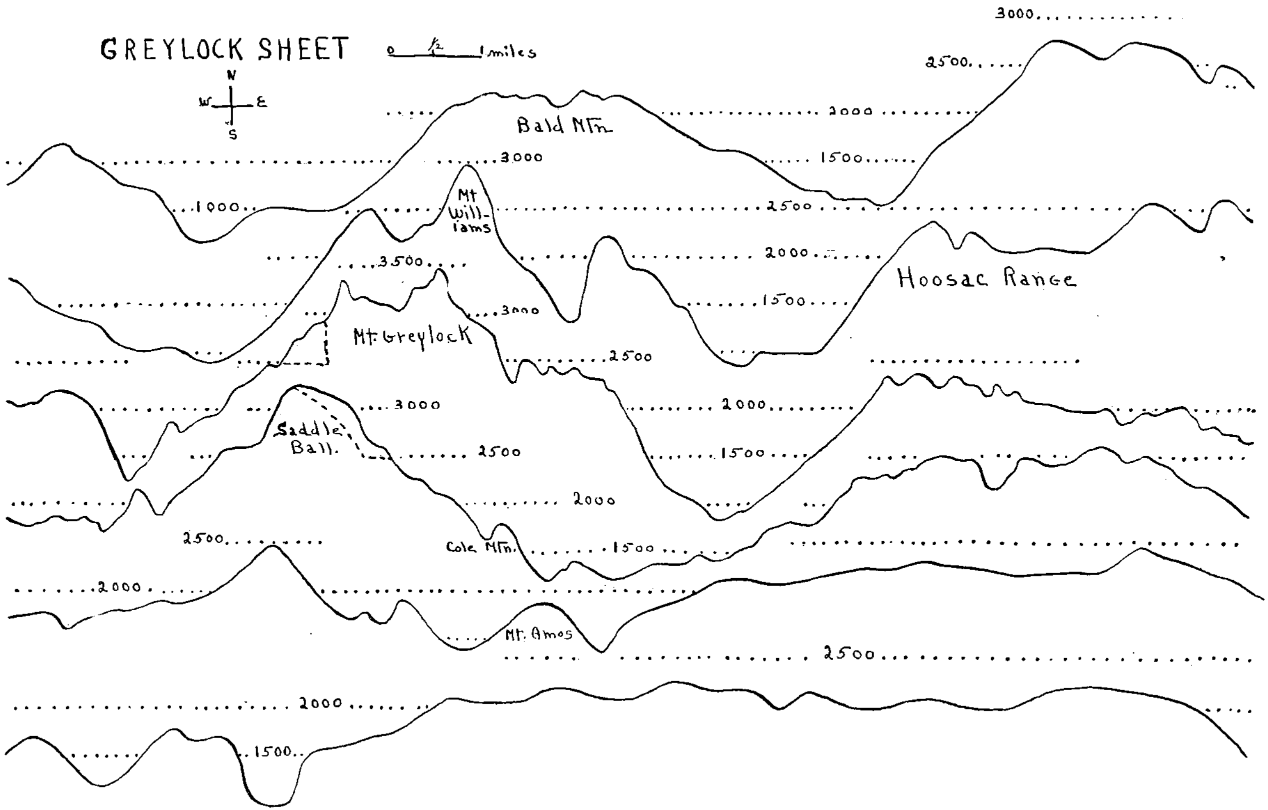

FIGURE 43.—Generalized east-west profile of the Greylock Sheet.

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THE EROSIONAL LANDFORMS OF EASTERN AND CENTRAL VERMONT

Howard A. Meyerhoff and Marion Hubbell

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INTRODUCTION

The main outlines of the physiographic development of New England appeared to be settled definitely by the scholarly work of William Morris Davis[1] as long ago as 1895. For years his opinion of the upland of southern New England as a simple, single-cycle erosional surface of fluvial origin, tilted to the south and east from an axis of arching which apparently lay in the Taconic and Green Mountains sections, was generally accepted. In 1912, however, the opinion was seriously questioned by Joseph Barrell, who presented before the Geological Society of America a preliminary conclusion that the uplands of the Northern Appalachians are far more complex than had been thought, and that the erosional features are predominantly marine rather than

[1] Davis, W. M., The physical geography of southern New England. The Physiography of the United States, National Geog. Soc., National Geog. Mon. I, No. 9, 1895, pp. 269-304.

fluvial. His opinions were published only in abstract,[1] and it was the tacit attitude of most workers in the northern Appalachian region that the burden of proof lay with the author of these heretical views. The attitude is reflected in the work of A. K. Lobeck[2] who, following the interpretations of Davis, examined the extension of the southern New England peneplane into New Hampshire and found it terminating with topographic unconformity against the base of the White Mountains. It is seen at a still later date, after Barrell's conclusions had been elaborated, in the work of George W. Bain,[3] who, however, recognizes two Tertiary erosional surfaces in addition to the Cretaceous peneplane; and in the study of the fall-line by George T. Renner, Jr.,[4] who still utilizes the Davis point of view, though he is inclined to correlate the New England upland with the Piedmont and to date both as Tertiary, relegating the recognized Tertiary level to a later Tertiary date of origin.

Prior to their posthumous elaboration and publication under the editorship of H. H. Robinson,[5] Barrell's views appear to have gained but a single supporter, Laura Hatch, who, in a field survey of the Stonington quadrangle in southeastern Connecticut, identified a series of five terraces, which she interpreted as marine in origin.[6] The fuller presentation of Barrell's conclusions in 1920, however, won for them a much wider acceptance, which was ably furthered by Florence Bascom's studies in the Piedmont province of eastern Pennsylvania.[7] Her review of the erosional features in the northern portion of the Piedmont supports Barrell's contention for many cycles but ascribes a much larger share of the destructional work to fluvial processes. Although a few other contributions bearing directly or accidentally on the problem as it concerns New England have been made since 1920, practically nothing of decisive and definitive character has been published either to refute or to prove the marine, multi-cycle hypothesis of Barrell, or to support the fluvial, mono-cycle theory of Davis.

The views of Davis and Barrell are too well known to require extended exposition. According to Davis, mountainous New England was reduced to a peneplane presumably at the close of

[1] Barrell, Joseph, The piedmont terraces of the Northern Appalachians and their mode of origin; Post-Jurassic history of the Northern Appalachians; discussion by Frank Leverett, D. W. Johnson, W. M. Davis, M. R. Campbell, and N. H. Darton, Bull., Geol. Soc. of Amer., Vol. XXIV, 1913, pp. 688-696.

[2] Lobeck, A. K., The position of the New England peneplane in the White Mountain region, Geog. Rev., Vol. III, 1917, pp. 53-60.

[3] Bain, George W., Geologic history of the Green Mountain front, Rpt. Vermont State Geologist, 1925-26, pp. 222-241.

[4] Renner, George T., Jr., The physiographic interpretation of the fall-line, Geog. Rev., Vol. XVII, 1927, pp. 278-286.

[5] Barrell, Joseph, The piedmont terraces of the Northern Appalachians, Amer. Jour. Sci., 4th ser., Vol. XLIX, 1920, pp. 227-258; 327-362; 407-428.

[6] Hatch, Laura, Marine terraces in southern Connecticut, Amer. Jour. Sci., 4th ser., Vol. XLIV, 1917, pp. 319-330.

[7] Bascom, Florence, Cycles of erosion in the Piedmont Province of Pennsylvania, Jour. of Geol., Vol. XXIX, 1921, pp. 540-559.

Cretaceous time. The erosional surface is rather perfect in Connecticut, Rhode Island, Massachusetts, and southeastern Maine; but northward and westward it is broken by an increasing number of monadnocks, which are so numerous in Vermont and New Hampshire that they constitute the dominant feature in the topography. In the White Mountains section of New Hampshire, as Lobeck has shown, the clustered residuals, carved from massive and nearly homogeneous rocks, rise with sharp topographic unconformity above the so-called New England peneplane. In Vermont the structurally controlled linear ridges embraced in the Green Mountains section have been assumed to possess the same relationship to the erosional surface of southern New England. In the narrow belt along the western border of Massachusetts and Vermont, where the rock-section is composed of alternating members of exceptional resistance and of exceptional non-resistance, the latter have been excavated into lowlands which coincide closely with the extent of the soft-rock members, and which lie nearly 1,000 feet below the level of the adjacent New England upland, while the hard-rock members rise as high above it. The topography is in consequence so distinctive that this narrow belt has been treated as a separate sectional division in the New England province and is known as the Taconic section.

According to Davis the cycle of peneplanation which leveled southern and eastern New England was cut short at the close of the Cretaceous period before the resistant rocks of northern New England were reduced. The uplift was accompanied by warping, and the arched surface is now 100-300 feet above sea level at the coastline and rises gradually to 2,000 feet in the northwestern corner of Massachusetts and in the south central part of Vermont. The Davis interpretation recognizes the importance of Tertiary dissection in opening out broad lowlands coincident with the soft rocks infolded and infaulted into the resistant metamorphic and igneous matrix which composes most of New England, but refers all post-Cretaceous and pre-glacial erosion to one or two cycles.

An analysis of a series of profiles of the upland led Barrell to conclude that its surface rises not in a simple low arch, but in a series of eleven broad terraces or benches, which ascend like a flight of steps from Long Island Sound northward and northwestward into the interior. He found that each terrace is separated from the next higher and the next lower one by a relatively steep slope, which not infrequently forms a definite erosional scarp. Each of these benches, Barrell reasoned, represents the record of a distinct and independent cycle, preceded and terminated by uplift. The rising elevation northwestward was thus imparted to New England not by the arching of a simple erosional surface, but by a succession of essentially vertical movements, which elevated the erosional benches as rapidly as they were planed. Each successive bench was cut a shorter distance into the upland, and, although it has undergone a cumulative amount of fluvial dissection since uplift, enough has been spared to form a recognizable element in the topography. Impressed by the low angle of seaward slope of the terraces, by the noticeable topographic break between each of them, and by their relative independence of underlying structures, Barrell was led to postulate a marine origin for all but two of them.

An interpretation more diametrically opposed to Davis's view could not have been devised, and it is surprising that it should have provoked so little corroborative investigation in New England up to the present time. With the main issues of physiographic development unsettled, little progress is possible even in detailed investigations of special or local problems. Such studies are bound to reflect the underlying chaos. For example, Renner[1] gives expression to an opinion which, since the appearance of Barrell's work, has been gaining headway among many physiographers who still hold to the Davis hypothesis; namely, that the New England peneplane is to be correlated with the Piedmont peneplane, and that both are Tertiary. Evidence of such a correlation has not been offered, and an attempt to prove it by map, profile, and field work has led the authors to a preliminary conclusion which must await more detailed work for confirmation; namely, that the upland of southern Connecticut and southeastern New York is to be correlated in part with the Piedmont, but that the upland of western Massachusetts continues without break southwestward in the flat-topped ridges of Reading Prong which have been correlated with the Cretaceous, or Schooley peneplane of the central Appalachians. No one would venture the opinion that the ridgecrests of Reading Prong and the erosional surface of Westchester and Putnam counties of New York (which lies some 700 feet lower in elevation), were formed contemporaneously. Yet a wholesale correlation of the New England peneplane with the Piedmont, or its assignment to a Tertiary age, involves by implication this kind of contradiction.

The present paper does not pretend to offer the final solution of New England's erosional history, although it reviews—perhaps too ambitiously—the main problems in the light of the physiographic features of part of Vermont and Massachusetts. The investigation began more modestly as a study of the relation of the New England upland to the Green Mountains. In this question the senior author's interest was aroused in 1919 by Professor Douglas W. Johnson, whose course in the physiography of the Eastern United States suggested it. At that time a study of the

[1] Renner, George T., Jr., *op. cit.*, p 281.

problem was undertaken with a strong bias to Davis's point of view, but the investigation had to be discontinued and was not resumed until the latter part of 1926, when the authors of this paper again took it up. The investigation was begun a second time with the frank intention of avoiding the issues raised by Barrell, although it was hoped that some contribution might be made toward their ultimate solution. Avoidance of the issues seemed possible because Barrell conceded the fluvial origin of the oldest terraces in northwestern Massachusetts,[1] and because field observations soon made it plain that all of the landforms of Vermont had been developed by fluvial processes. It was thought that, even if there were more than one level, the Green Mountains would rise from the highest, and that in a local problem of the kind no final commitment concerning the number of levels in southern New England or the geologic agent involved in their formation would be necessary.

Laboratory and field work was thus begun north of Deerfield River upon that portion of the New England upland which Barrell designated as the Canaan terrace.[2] Profiles and field traverses were made north from this locality and east and west between the Taconic section and Connecticut River. Up to the present time the area bounded roughly by Deerfield, Connecticut, and White rivers and by the Taconic section has been studied intensively, and many uncorrelated observations have been made in the north central portion of Vermont between Lamoille River and the Canadian line (Figure 44). Difficulties appeared early and multiplied as the work progressed. The Canaan terrace in the Hawley quadrangle north of Deerfield River resolved itself into two distinct erosional levels, and a third was clearly present in the immediate neighborhood of the river. Toward the Connecticut several levels appeared, although from Barrell's map only one was to be expected. Later the high linear ridges of the Green Mountains were found to rise not from a single level, such as the Becket terrace, as Barrell's work implies; on the contrary, in different localities they rise with topographic unconformity from erosional surfaces that vary as much as 1,000 feet in elevation. In brief, it became obvious that a solution of the local problem which the writers had undertaken was so intimately interwoven with the physiographic development of all New England that a definite conclusion with regard to the regional problems had to be

[1] Barrell, Joseph, *op. cit.*, p. 231. The unfinished character of Barrell's work is manifest in what appears to be inconsistency on this point. On later pages he speaks of the indeterminate origins of the Cornwall, Canaan, and Becket terraces in consequence of the long operation of fluvial processes upon them; and still later he concludes that the Becket terrace is marine, and that its inland limits represent the Cretaceous shoreline.

[2] *Idem*, pp. 247 and 413.

reached, or the local problem abandoned. The former alternative was chosen.

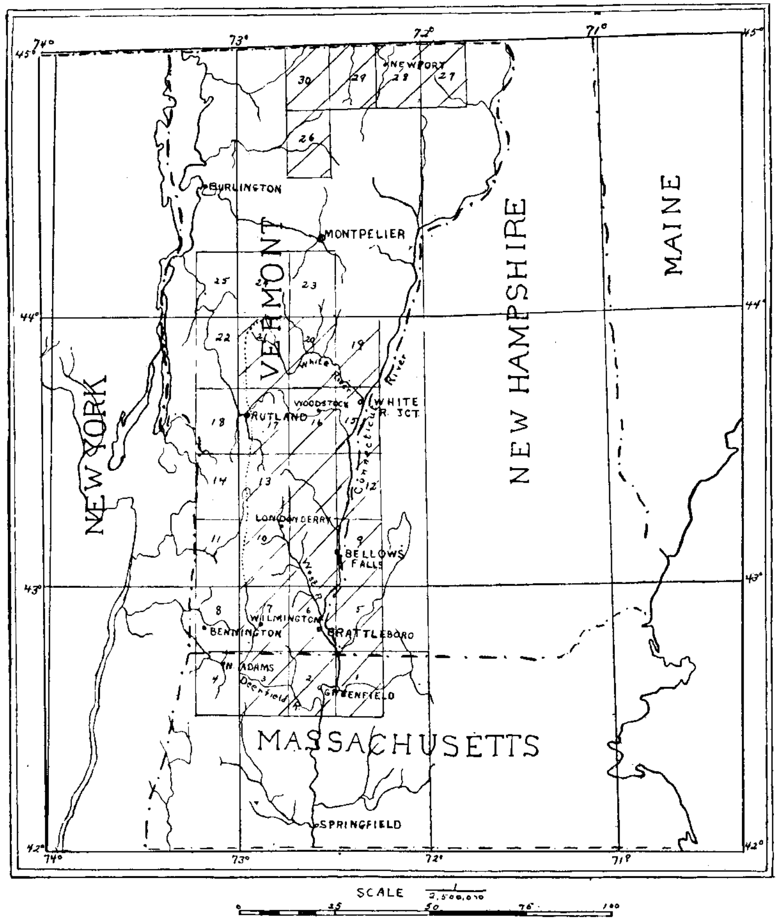

FIGURE 44.—Location map showing areas studied. Shaded areas were studied in the field and were analyzed by profiles. The numbers refer to the topographic maps of the U. S. G. S., as follows: (1) Warwick; (2) Greenfield; (3) Hawley; (4) Greylock; (5) Keene; (6) Brattleboro; (7) Wilmington; (8) Bennington; (9) Bellows Falls; (10) Londonderry; (11) Equinox; (12) Claremont; (13) Wallingford; (14) Pawlet; (15) Hanover; (16) Woodstock; (17) Rutland; (18) Castleton; (19) Strafford; (20) Randolph; (21) Rochester; (22) Brandon; (23) Barre; (24) Lincoln Mountain; (25) Middlebury; (26) Hyde Park; (27) Island Pond; (28) Memphremagog; (29) Irasburg; (30) Jay Peak.

Detailed consideration of the erosional history of southern New England was far too vast a project for the present study; and the writers had to content themselves with the construction of a limited number of north-south profiles extending from southern Vermont and southwestern New Hampshire to Long Island Sound, and a series of northwest-southeast profiles from the northwestern side of the Reading Prong to Long Island Sound was also prepared and studied. Brief field inspection of a few critical areas in southeastern New York, northern New Jersey, and western and central Massachusetts was made, but the work done in the southwestern portion of the New England physiographic province was so cursory that the conclusions reached are general and must ultimately be revised on the basis of more thorough studies, which are projected or in preparation. Yet, the general conclusions warranted by preliminary study are pertinent to an understanding of the physiographic problems in Vermont and will be set forth as an integral part of the present report.

THE EROSIONAL LEVELS OF WESTERN NEW ENGLAND

Opinion regarding the number of erosional levels in the Appalachian region is extremely varied, even if the trend of recent works be not considered. Keith's discriminating studies have differentiated seven in the southern Appalachians.[1] Campbell recognizes three in the central Appalachians,[2] and some authors believe that the crest of Kittatinny Ridge may mark the position of a fourth, which is higher and older than the Schooley peneplane. In New England two have been generally recognized, but Bain adds a third[3] on the basis of evidence for two Tertiary cycles in the Champlain lowland and in the Connecticut valley. A fourth has been suggested by C. H. Richardson[4] at an elevation of 3,000 feet or slightly more, because of the large number of peaks and ridges which rise to this altitude. The problematical Boott spur on the flank of Mount Washington has likewise been interpreted as the remnant of a much older erosional plane, but denudation has reduced so much of New England below the altitude of Boott spur that the possibility is unconfirmed for lack of additional evidence.

With the exception of Keith, Barrell, Hatch, and Bascom, most physiographers have been content to work with a small number of cycles, and not a few have tended to reduce Appalachian erosional history to the bare minimum of two—a Cretace-

[1] Keith, Arthur, Some stages of Appalachian erosion, Bull. Geol. Soc. Amer., Vol. VII, 1896, pp. 519-525.
[2] Campbell, M. R., Geographic development of northern Pennsylvania and southern New York, Bull. Geol. Soc. Amer., Vol. XIV, 1903, pp. 277-296.
[3] Bain, George W., *op. cit.*, p. 236.
[4] Richardson, C. H., Areal and economic geology of northeastern Vermont, Rpt. Vermont State Geologist, 1905-06, pp. 71 and 73.

ous and a Tertiary. By analyzing the levels referred to the Harrisburg cycle in the central Appalachians, Barrell has shown[1] the inconsistency which must result when too few erosional levels are employed. Similar inconsistencies are to be found in physiographic studies of New England. One example—the only one dealing pertinently with the physiographic history of Vermont—may be cited. In the "Geologic History of the Green Mountain Front,"[2] Bain's interpretations are limited by the necessity of fitting all high erosional surfaces into a "Cretaceous peneplane." In a series of seven profiles across the Green Mountains and Taconic sections he shows the latter at an elevation ranging from 1650-1850 feet; but, finding unmistakable levels in the Taconics at 2,000-2,200 feet and at the base of Stratton Mountain at 2,300-2,400 feet, he is constrained to refer them to the much lower surface shown in the profiles. All are in consequence regarded as part of the peneplane formed during the Cretaceous cycle.

Confronted with the same dilemma in a small area along Deerfield River and along the southern state boundary, George D. Hubbard interpreted the topographic features without the constraint of a theory which admits only a single Cretaceous erosional surface at the elevations involved.[3] His conclusions will bear quotation: "Physiographically the area is a part......of the maturely dissected, glaciated upland, a partial peneplain with monadnocks......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 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."

Hubbard establishes this elevation of the surface formed during the first cycle as 2,200-2,400 feet; that formed during the second, as 1,700-1,900 feet; whereas 1,400 feet represents the

[1] Barrell, Joseph, *op. cit.*, pp. 333-338.
[2] Bain, G. W., *op. cit.*, pp. 232, 234, and Plates XXVIII, XXIX, XXXII.
[3] Hubbard, G. D., Geology of a small tract in south-central Vermont, Rpt. Vermont State Geologist, 1923-24, pp. 260-344. Quotations and altitudes are taken from pp. 262-263; 322-330.

lowest level which has been reached during the third. He regards the features referable to each cycle as wholly fluvial in origin, and his excellent exposition of the facts gives convincing support to his belief in several cycles. A re-study of the Deerfield drainage area indicates that even a larger number of levels is preserved in the region embraced by his investigation, and that several later ones are present farther downstream. Although Hubbard's views concerning the ages of the erosional surfaces and their place in the erosional history of New England cannot be accepted, he is, so far as the writers have discovered, the only geologist, with the exception of Barrell, who has recognized the need of resolving the higher portion of the New England upland in Vermont into several levels formed during distinct cycles.

The authors of this paper began their study of the physiographic features of southeastern and central Vermont expecting that the upland flanking the Green Mountains on the east and south would prove to be a mono-cyclic, fluvially formed surface, equivalent to the New England peneplane of Davis in northwestern Massachusetts. The Cretaceous age of this surface was questioned, and its equivalence to the Tertiary Piedmont was suspected; hence, it was hoped that a higher Cretaceous level might be differentiated within the Green Mountains. Preliminary work indicated that a lower level was to be expected in the neighborhood of the Connecticut, and that it might also extend for moderate distances headward along major tributaries. In the field, however, the writers were beset by the same choice that confronted Bain and Hubbard. Several distinct and persistent erosional surfaces competed for recognition as the New England peneplane, and there was equally strong competition among the series of lower levels associated with the Connecticut and its large tributaries. Most of these levels were differentiated both in the field and in the laboratory, before any comparisons were made with the terraces which Barrell had distinguished in New England and with those which Adela M. Pond has recently identified in the Taconic section.[1] The comparison (Table I) yielded a result so surprising that it may well serve as a point of departure for the discussion that follows.

The close agreement among determinations obtained in three distinct, but contiguous areas by workers who did not use identical methods, and who were not guided by each other's results can hardly be regarded as an accident. The minor discrepancies, moreover, may be simply explained: Barrell's profiles do not ex-

[1] Miss Pond has studied the erosional landforms of the Taconic section, and her report, "Peneplanes of the Taconic Mountains of Vermont," appears elsewhere in this volume. The authors gratefully acknowledge her kindness in placing in their hands a manuscript copy of her paper, from which the figures in the accompanying table have been taken.

tend into the higher altitudes of northern New England, hence the two levels which are found above the Becket terrace both in the Green and Taconic Mountains did not come to his attention. Little of the Taconic section has been excavated below 600 feet, and in some localities elevations below 800 feet do not occur; hence the lowest terraces are not present. It must be assumed that Miss Pond considers the evidence for the 1,200-foot and 1,400-foot terraces too inconclusive to give them a place in her series, for several of the writers' profiles, which extend from Connecticut River into the eastern part of the Taconic section suggest that fragmentary terraces and surfaces graded to these elevations are locally present.

TABLE I

Comparison of Erosional Levels in Southern New England and Vermont

Southern New England Barrell		Taconic Section Pond	Eastern and Central Vermont Meyerhoff and Hubbell
Name	Elevation	Elevation	Elevation
Dorset[1]	****	3,200	(?) 3,000(?)-3,200
Braintree[1]	****	2,700	2,700-2,800
Becket	2,450	2,500	2,300(?)-2,500
Canaan	2,000	2,000	2,000-2,150±
Hawley[1]	****	****	(?) 1,820-1,920
Cornwall	1,720	1,700	1,660(?)-1,720
Goshen	1,380	****	1,360-1,420
Litchfield	1,140	****	1,180-1,240
Prospect	940	900±	(?) 980-1,080(?)
Towantic	740	700+	780- 900(?)
Appomattox	540	****	540- 620(+)
New Canaan	450	****	420- 480
Sunderland	240	****	(?) 260- 300
Wicomico	120	****	(?) 160- 180

[1] The name Dorset has been proposed by Pond; the names Braintree and Hawley are proposed in this paper; all others are Barrell's.

In Table I the writers have questioned terrace-elevations of which they are not wholly sure; and in cases where there is any reason to doubt the identity of an entire terrace, the figures are preceded by a question mark. Doubt was felt regarding the 3,000-3,200-foot level because of the scattered and fragmentary character of the evidence for its existence; and for this reason, too, the minimum elevation to which the surface was graded cannot be definitely ascertained. The authors have differentiated a level at 1,820-1,920 feet between the Cornwall and Canaan terraces of Barrell. They have questioned its identity notwithstanding its conspicuous development in western Massachusetts and in many widely-scattered portions of Vermont, because in the field and

laboratory it often proved difficult to separate it sharply from the Canaan level. It may have been for this reason that Barrell left it out of his series, for he was convinced of its presence in 1911.[1] Supplementary field studies are necessary before it can be accorded a permanent place. The Prospect and Towantic levels gave similar trouble, but in this case the identity of the higher one was difficult to establish. The two lowest levels are questioned merely because their presence was determined largely from map study and profiles. Field evidence was not sought to establish their presence in Vermont, and the map and profile study was undertaken as an afterthought, when it was discovered from Barrell's list of terraces that all his other erosional levels have correlates in the southern and central parts of the state. The maps leave no doubt, however, that the two latest cycles have also left their impression upon the region.

The range in altitude which has been given in the table for each of the terraces includes two features: first, the local relief exhibited by topographic forms which were graded to each given baselevel; and second, the regional gradient, or general rise of the level northward and westward. In general, the rise in elevation of each erosional plane is slight northward, but is considerably more rapid westward. This feature is normal in a series of fluvial levels and is a natural consequence of the more rapid rise in the gradients of the tributaries than in the gradient of the Connecticut in each successive cycle. The fact that the minimum figures given for many of the levels in southeastern and central Vermont are lower than those given by Barrell for the same level in southern New England is partly explained when it is noted that Barrell's figures represent maxima only. The discrepancy is due in larger part, however, to the fact that Barrell based his figures on the elevations of interfluvial ridges; the authors, on the other hand, regarded the elevations of the inter-stream divides as local maxima for the vertical range of a level. Minimum elevations were determined from the altitude at the tops of the erosional scarps which separate each of the terraces. This difference in choice of criteria is based fundamentally upon opposed theories of terrace-origin. If the terraces be marine, the original surface is preserved only in the ridge-crests; if fluvial, the latter must be regarded as the high points on the erosional surface.

Two sources of error must be taken into account when definite elevations are assigned to the erosional surfaces: The first is glaciation; the second is the amount of dissection which the surface has undergone since initial uplift. The amount of error, which varies from place to place and from terrace to terrace, is difficult to evaluate, and no attempt has been made to estimate

[1] Barrell, Joseph, *op. cit.*, p. 238.

it. The original surface was higher by the amount of soil, subsoil, and rock which was removed by the ice sheet. For the most part, the effects of glaciation upon the terraces not located within deep and narrow north-south valleys were relatively slight and were restricted to soil removal, polishing, grooving, and plucking. With local exceptions the amount of material removed was probably not great. Graded slopes appear to have remained practically unmodified, and confidence is felt that glaciation destroyed little of the evidence upon which conclusions concerning the origin of the erosional terraces must be based. In many of the large north-south valleys in the central portion of the state, on the other hand, glaciation was a potent agent of destruction. Terraces and graded valley slopes are gone or are preserved as misshapen, isolated remnants, pushed back against the valley walls. Determination of the relation of these remnants to a given erosion level is difficult, and interpretations, unreliable in many instances, too frequently appear forced. In the majority of cases, however, it is possible to correlate them with less glaciated erosional surfaces in a nearby area.

Fluvial dissection of a land surface progresses in two ways: The upland surface is gradually lowered by rainwash, and it is destroyed by gullying and sapping. As the latter processes work headward from the main streams, the portions of the upland still preserved occupied comparatively high situations on the graded erosional surface, assuming that the position of the main streams has not materially shifted. The more extensive the dissection, the higher must have been the areas still preserved with reference to stream levels during the cycle. If, then, figures for the minimum and maximum elevations of a terrace are based solely on the remnants which still exist, the lower figure must be too high, and the higher figure too low, and the result is a reduction in the true relief of the original surface. Some correction may be made by projecting graded slopes to the position of the old valley floors, but this has not been attempted in the present investigation.

It seems reasonable to assume that the differentiation of many erosional levels in contiguous portions of New England by independent workers is more than an accident. The observations of Barrell, Hubbard, Pond, and the writers are in complete agreement not only with regard to the presence of many terraces but with regard to the positions which they occupy. If more testimony is demanded, the profiles which Lobeck published in his paper on the White Mountains[1] may be re-examined: From the Atlantic coast to the mountains the upland surface ascends in a series of steps, each comparatively flat-topped, each separated from the other by moderately steep scarps. The mountains rise

[1] Lobeck, A. K., *op. cit.*, Plate II, Figures 2, 3, and 5.

prominently from lower steps than those from which the Green Mountains rise, but in other respects Lobeck's profiles differ little from Barrell's. No effort has been made to correlate the levels in the two sections, but the terraces between Connecticut River and Mount Monadnock, at least, match those in Vermont.

The fact that the terraces may be correlated accurately from one portion of western New England to another, and the fact that they lie approximately at the same elevations in river systems that drain into Long Island Sound, the Hudson, and the St. Lawrence, imply that these levels are not to be explained as local features referable to local phases of river development. They reflect events of regional significance. The explanation seems at hand: They reflect regional uplifts and represent the degradational forms which developed during the cycles of quiescence that followed upon the uplifts.

Although it can scarcely be denied that the New England upland is a terraced upland, it is possible, however, that the terraces may be explained on some basis other than the assumption of many cycles. The other possibilities must be examined.

POSSIBLE EXPLANATIONS FOR THE PRESENCE OF TERRACES

In the identification of a series of terraces occupying broad upland areas it is necessary to discriminate between true cyclical levels and ordinary erosional features which may assume the appearance of levels. If an upland surface is tilted, monadnocks may give a misleading impression of terraces; features of differential erosion may yield forms that simulate terraces; and in regions of favorable geologic structure, step-like rises in the topography may be developed in the course of a single cycle. It is always possible, moreover, for terrace-like forms to be imparted to a surface by faulting or warping. These possibilities, so far as they need be considered in connection with the erosional levels of New England, have such diverse merits that they will be discussed individually.

DIASTROPHIC INTERPRETATIONS

It is possible that the Cretaceous peneplane has been given a terrace-like aspect in consequence of irregular warping or faulting, and the terraces may thus be an initial diastrophic feature. This possibility was considered by Barrell and may be dismissed with his statement:[1] "Irregular warping or faulting cannot account for the step-like character of the skyline, for the margins of the steps are sinuous lines, best seen on the maps, but well

[1] Barrell, Joseph, *op. cit.*, p. 250.

seen on the profiles where a lower baselevel passes in between the outposts of a higher level."

Barrell also points out that the persistence of each bench at the same elevation over broad areas is proof of the regularity and regional character of the movements which have affected it, and that such regularity could hardly have been imparted by warping and faulting. The narrow terraces which parellel mainstreams and tributaries in northern New England, moreover, can by no stretch of the imagination be explained in this way.

ERRONEOUS INTERPRETATIONS BASED ON MONADNOCKS

When Barrell presented his hypothesis in 1912, D. W. Johnson called attention to a serious danger, which the authors have found in very real one: "If we have an uplifted and tilted peneplane on which there are monadnock residuals, it is possible to select positions in which terrace profiles can be drawn similar to some of those on which Professor Barrell bases his conclusions in favor of marine planation."[1]

FIGURE 45.—Apparent terraces on a tilted erosional surface.

The danger to which Johnson directs attention is illustrated simply in the accompanying diagram (Figure 45), in which the line a-a′ represents in profile the sloping erosional surface, whereas 1, 2, and 3 represent apparent terraces. In cases where the peneplane is not tilted, on the other hand, the indiscriminate use of monadnocks exposes interpretations to an equally serious risk. If, in New England, the most southerly monadnock which attains the elevation of a given terrace be taken as its seaward boundary, the significance of lower levels north of the monadnock may be overlooked. An examination of the Canaan terrace, as represented in the projected profile accompanying Barrell's paper,[2] suggests that, by considering the monadnock at N. W. 53 as the seaward margin of this terrace, he has disregarded the well-developed surface ranging from 1,800-1,900 feet between it and the more northerly area where the Canaan level is the predominant element in the upland. As noted above, Barrell recognized an erosional surface at 1,840 feet in the field, but his method of determining the seaward limits of terraces from the position of monadnocks caused him to neglect the level in his profile studies

[1] Bull. Geol. Soc. Amer., Vol. XXIV, 1913, p. 691.
[2] Barrell, Joseph, *op. cit.*, Plate V (facing p. 422).

and, possibly, caused him to place too much faith in his marine theory of terrace formation.

If the elevation and position of monadnocks are the principal criteria used for the determination of levels, then the danger of which Johnson warns is a serious one. In any case it makes interpretations based on a small number of profiles, especially if the profiled belts are not adjacent, both hazardous and unreliable. For this reason, in the present study monadnocks were scarcely utilized as a means of determining the position of erosional levels, except for the postulated surface at 3,000-3,200 feet. No level was accepted until profiles, map study, and field observations demonstrated (1) that it is represented in all parts of southern and central Vermont to which headward erosion must have proceeded during the cycle under consideration, and in which subsequent events have permitted its preservation; (2) that the areas reduced with respect to each baselevel are large enough to show gradation toward a constant minimum elevation (the minimum figures given in Table I); (3) that each level is bounded by clear-cut erosional scarps which, in some cases at least, are independent of structure and lithology. Supplementary criteria, which were used wherever possible, include accurate correlation of levels associated with different stream systems, discordance of stream gradients within the range of elevations determined for each erosional surface, concordance of wind-gaps with respect to certain erosional planes, accordance of monadnocks lying outside the areas in which a given level is the principal element. In brief, no single criterion was considered adequate to prove the existence of a level, and it was felt that all available lines of evidence must converge to establish its validity.

It is possible to select any single line of evidence employed in the identification of a series of terraces and to demonstrate its unreliability. No one recognized this fact better than Barrell, and he was careful to utilize convergent proofs to support his conclusions. It is the weakness of most attacks on his terrace theory that they concentrate upon the fallibility of some one type of evidence which he employed, such as monadnocks, wind-gaps, the influence of rock-resistance and structure in the preservation of levels, etc. But the breaking of one isolated strand after another in the closely-woven fabric of his theory offers little assurance that the structure of the whole is not strong and sound.

RESISTANT BARRIERS AND TERRACE DEVELOPMENT

A much more serious possibility arises from the consideration that two or more erosional terraces may be formed in the course of a single erosion cycle by streams that are superimposed across hard-rock barriers. A case may be assumed: A peneplane is developed on folded strata which strike north-south. The mainstreams drain toward the east and are fed by north-south subsequent tributaries which flow in the soft-rock belts. The peneplane is upraised, and the mainstreams quickly regrade themselves headward as far as the first resistant rock upon which they have been superimposed. That is worn down so slowly that the entire soft-rock area behind it is planed as rapidly as the stream channel is lowered at the barrier. A second hard-rock stratum, situated farther west, may likewise impede gradation of still another area, and before the second cycle is far advanced a series of terrace-like levels will be developed (Figure 46).

A structural lowland which has been commonly cited in illustration of this principle is the Berkshire valley, the southern portion of which is drained by Housatonic River. Its broad, flat surface, 700-1,000 feet above sealevel, is approximately as wide

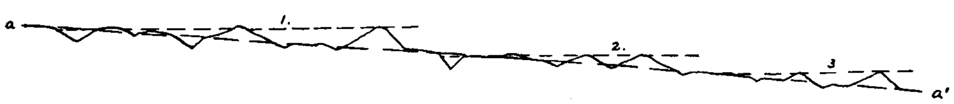

FIGURE 46.—Fluvial terrace development behind resistant barrier.

as the limestone belt which underlays it. The limestone forms a pitching syncline, and where the synclinal structure ends, the Housatonic flows southeastward through resistant metamorphics, in which it has carved a relatively young valley. It is claimed that the Housatonic valley is maintaining itself at grade with respect to its outlet and is being corraded vertically and laterally as rapidly as the lowering of the outlet permits. The authors are willing at the present time to concede that this is a possible interpretation, but they wish to point out that the presence of several matched erosional terraces on both sides of this lowland, corresponding with the elevations of monadnocks within it, suggests a cyclical history. It is suspected that its present form and elevation are genetically related to the development of one or two of the erosional terraces in the New England upland to the south and southeast. This possibility needs investigation.

It must be granted on theoretical grounds that this mode of terrace development is possible in the early and intermediate stages of the erosion cycle; and inasmuch as New England, according to the Davis theory, has not been dissected beyond this point in the course of Tertiary and Quaternary denudation, the explanation must be carefully examined. Obviously it cannot apply once maturity of stream development is attained; for in mature and post-mature stages the mainstreams are graded, discordant features, such as waterfalls and rapids, are eliminated,

and the soft-rock areas are graded with respect to absolute base-level. The Harrisburg peneplane of the central Appalachian region illustrates this point perfectly. Formed chiefly on the soft-rock areas in the Appalachian folds, its development was dependent upon the ability of the superimposed mainstreams to grade themselves across the hard-rock ridges. So perfectly was this done, that the elevations of the Harrisburg surface are relatively accordant even in widely separated and distinct stream systems. The central Appalachian region, however, affords an interesting commentary upon the likelihood of extensive terrace formation by the method under consideration. Since the development of the Harrisburg peneplane, uplift and entrenchment have occurred. For the moment one cycle of entrenchment may be assumed; but, as Barrell's work shows, the relation between the present features of entrenchment and the erosional level formed in the next preceding cycle is the same, however many cycles are recognized in Pennsylvania. Entrenchment of the mainstreams has taken place throughout the greater part of the area, even though the latest cycle has not as a whole passed through youth. Differential rock-hardness has certainly offered an unparalleled opportunity for the subsequent tributaries to open out broad lowlands in non-resistant rocks at the new level; but the authors are not acquainted with a single area where this has occurred. The subsequent tributaries are on the whole less perfectly adjusted to the present cycle than are the superimposed mainstreams. Thus, in the one region where mono-cyclic erosional terraces have had an unparalleled opportunity to develop in progressively more remote soft-rock areas, they have signally failed to do so.

When the attempt is made to apply this explanation to the terraces of New England, its inapplicability soon becomes apparent. In western and central New England the terraces are not developed with respect to rock barriers, although there are many hard-rock elements which might have served the purpose, and superposition of streams is a common phenomenon. In most cases, on the contrary, the general trend of the terraces is transverse to the structure, except in central Vermont, where terraces and geologic structures are parallel. With the exception of a few special cases, like the Housatonic and Hoosic valleys, the arrangement of streams and structural features has offered little or no opportunity for mono-cyclic terrace formation, and very commonly the terraces are most perfectly developed in areas of homogeneous rocks. Still another consideration precludes the "rock-barrier" hypothesis: If lateral planation in soft-rock valleys is assumed to keep pace with the lowering of their outlets, although it is conceivable that isolated, unmatched erosional terraces may develop in much the same way that alluvial terraces are formed under comparable conditions, it would be wholly impossible for symmetrical terraces to be cut. Yet along the valley of West River, especially north of Newfane, and in many portions of the valley of the Deerfield and its tributaries, as in the neighborhood of Searsburg, in the vicinity of West Dover, and in the Londonderry topographic basin, to mention only a few cases, matched rock-terraces are conspicuous. Matched terraces are characteristic features of cyclic development, but the possibility that they may be formed by differential erosion invites consideration.

TERRACE DEVELOPMENT AS A PHASE OF DIFFERENTIAL EROSION

It is generally recognized that accordance of scattered peaks in a mountain region cannot be regarded as *ipso facto* evidence of a peneplane. Rough accordance can be imparted by normal erosion acting at a subequal rate on more or less homogeneous rocks. It is to be expected that, with uniform climatic conditions, weathering will act differentially upon rocks which differ in their resistance, reducing the softest to lowlands and those of intermediate resistance to intermediate elevations, while the hard ones are little affected. In a region where strata that vary in resistance reappear at the surface again and again in consequence of folding, it may be expected that the processes of differential erosion will fashion the country into a series of benches that may easily be mistaken for cyclical terraces. In synclinal valleys the repetition of the same stratum on either side of the valley would produce a matched-terrace effect typical of cyclical development. Even in monoclinal valleys cyclical erosion will produce results closely resembling those yielded by differential erosion. Criteria which will serve to differentiate the two types of terraces are of considerable importance.

Although Barrell recognized the influence of rock-hardness in preserving erosional terraces in the central Appalachians,[1] he did not discriminate between "pseudo-terraces" developed by differential weathering and cyclical terraces, the preservation of which was favored by lithologic factors. Discrimination is especially important in Vermont, because most of the topographic forms in the central part of the state are structurally controlled and involve to some extent the repetition of strata, which, as often as they have been repeated, tend to react the same way toward the agents of denudation within moderate areal limits. The authors of this paper must promptly admit that they have not made lithologic and structural observations correlative with their

[1] Barrell, Joseph, *op. cit.*, pp. 334-336; 342-348.

physiographic studies, and that additional data are desirable. With the problem of differential erosion in mind, however, a few random cases were studied, and confidence is felt that those selected are sufficiently typical to warrant a general conclusion.

The problem may again be approached by means of a theoretical case. A peneplaned syncline involving three formations of different degrees of hardness is upraised and eroded during a single cycle of erosion. On the arbitrary assumption that the oldest formation is the hardest, and that the youngest is the least resistant, a valley will be cut quickly to grade in the weak-rock belt and will be subsequently broadened to the full extent of the belt, while the rocks of intermediate resistance on either side will be lowered by weathering and rainwash at a slower rate, and the bounding hard-rock stratum will be reduced scarcely at all (Figure 47). If the stream in the weak-rock belt meanders, it may locally undercut the rocks of intermediate hardness, but elsewhere the slopes between the two formations will be gentle and graded. Once grade is attained, there is no practical limit upon the amount of lateral planation which may occur in the formation of intermediate hardness. The terrace-like profile will depend upon the amount of that formation which is unreduced by weathering and planation.

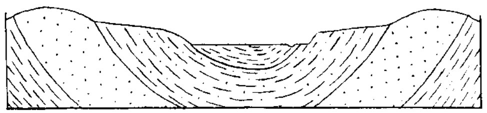

FIGURE 47.—Terrace development as a feature of differential erosion.

Suppose, on the other hand, uplift of the same structure occurs in two cycles, the second of which has been short in duration as compared with the first. During the first cycle the soft rocks will be excavated rapidly, and the intermediate rocks reduced by weathering and rainwash and, to some extent, by lateral planation. After the second uplift occurs, the soft-rock belt may be wholly excavated again, but in this case the erosional scarp between the older level and the younger will be ungraded, sharp, and discordant. This topographic unconformity, which separates the levels will, moreover, display complete or partial independence of lithology and structure (Figure 48). Coincidence with formation boundaries will be accidental. More complex cases of this kind are common in Vermont and western Massachusetts. The valleys of the Taconic section from northwestern

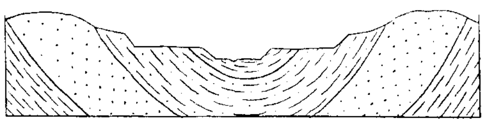

FIGURE 48.—Cyclical terraces in rock of different resistance.

Connecticut to Brandon are lined with them, and those in the northern part of this region have been accorded detailed study by Miss Pond. The valleys of Connecticut, West, White, and Deerfield rivers are likewise terraced in this fashion. Favorable lithologic and structural features may accentuate the terraces; but they are factors which locally modify but do not regionally control their distribution.

A broader view of the erosional levels of New England, moreover, serves merely to emphasize their independence of lithology and structure; the same formation often underlies lower and higher terraces at less or greater distances from the sea. True, the numerous monadnocks which rise above each erosional surface generally owe their existence to lithologic and structural causes. In this respect they are typical and support no one theory of development.

THE CYCLICAL EXPLANATION

Although terrace-like forms can be produced in any region by faulting and warping, or simulated in the course of a single fluvial cycle because of favorable lithologic and structural factors, clearly none of these possibilities applies in the case of New England. Errors of judgment arising from indiscriminate use of monadnock elevations and from reliance on the exceedingly fallible interpretations permitted by profile studies which are not supported by supplementary observations, have been scrupulously guarded against. Each type of evidence employed has acknowledged limitations, but the authors place some confidence in conclusions that are supported by the ensemble of criteria used. The more important of these criteria have been enumerated above, but further exposition of field and laboratory methods will be reserved for the concluding section, which deals in more detail with the characteristics of the erosional terraces in southeastern and central Vermont.

It seems certain that a categorical denial of the existence of numerous erosional levels in New England is out of the question, and that no alternative to Barrell's cyclical explanation of their origin applies. It must be concluded that each level affords evidence of a separate cycle of erosion, which was preceded and followed by vertical uplift.

The recognition of many cycles of erosion by no means implies the acceptance of a theory of marine planation to account for the features referable to each. It was noted above that Bascom was forced to modify Barrell's views[1] by ascribing a much larger place to fluvial denudation in eastern Pennsylvania;

[1] Bascom, Florence, *op. cit.*, pp. 540-559.

and that Hubbard regarded the three high levels which he studied in southern Vermont as fluvial in origin,[1] notwithstanding the fact that the highest of them was thought by Barrell to have been planed by the Cretaceous sea.[2] The possibility that the erosional landforms of northern New England represent fluvial phases of denudation, the development of which was contemporaneous with marine planation in southern New England must be rejected, because the minimum elevations of many of the levels in Vermont are lower than the elevations to which Barrell claims marine planation proceeded in southern New England. Hence Vermont could not have escaped partial denudation. Between the surface forms of the Vermont upland and those of the adjoining Massachusetts-Connecticut upland, moreover, there are no recognized differences which justify a supposition that the one area was fluvially reduced, the other, marine abraded. If the theory of marine planation applies to all of southern New England, it must apply in large part to Vermont. Examination of Barrell's theory is necessary, therefore, if the physiographic history of northern New England is to be correctly interpreted.

THE POSSIBILITY OF MARINE PLANATION

It is difficult to understand why Barrell attached so much importance to the theory of marine planation, for he was compelled to qualify it to an extent that largely vitiated its significance. He argues for the adequacy of marine abrasion as a means of planing broad benches, but when he applies the theory to the terraces in Connecticut, he is forced to conclude that each was merely wave-modified, rather than wave-formed. Wave-work was in all cases preceded by extensive fluvial denudation of the land-surface, and the sea obtained access to it as the result of submergence. Wave-erosion involved the development of a wave-cut cliff on the protruding interfluvial ridges, which were planed as the cliff was pushed back. The intervening drowned valleys served as repositories for estuarine deposits.[3] It is in this manner that Barrell explains the sinuous, fluvial pattern of the postulated shorelines, which, to judge from his description and from their distribution on the topographic maps, were still in a youthful stage of shoreline development when wave-work ceased. The assumption appears justified that each period of marine invasion must have been short as compared with the cycle of fluvial denudation which preceded it, for otherwise mature shore-forms would certainly be more common. Even if Barrell's modified theory of

[1] Hubbard, G. D., *op. cit.*, pp. 262-263; 322-330.
[2] Barrell, Joseph, *op. cit.*, pp. 417-418; 423.
[3] Barrell, Joseph, *op. cit.*, 233-234; 358-362; 410-412.

marine planation be accepted, surely the fluvial side of the story is entitled to more study than he has given it.

It is difficult to refute Barrell's modified theory, which calls for such short periods of marine planation that many of the more transient effects of wave-work would have been obliterated by subsequent subærial and glacial erosion, while the basic fluvial forms would tend to persist. Certainly it would be rash to deny, in the face of the evidence which demonstrates the oscillatory character of the strand-line, that the sea ever spread over any of the cyclical terraces. The difficulty of discriminating between marine-formed planes, marine-modified planes, and fluvial planes appears all but insurmountable in view of the lack of well established criteria by means of which these kinds of erosional surfaces may be differentiated.

There are, however, a number of reasons for questioning the applicability of a marine theory of origin, modified or unmodified, to the terraces of New England. It requires a unique and unlikely succession of diastrophic events. It demands profound fluvial dissection before each period of marine planation, but assumes that subærial processes have performed little work since. It assumes the unlimited capacity of waves to plane extensive areas, but it fails to account for any of the material removed in the process. It overlooks the distinction between fluvial and marine gradients, and in consequence erroneously interprets the low slopes of New England's terraces. Although it accounts for the fluvial boundaries of the terraces, it disregards the significance of their distribution and misinterprets the manner in which the fluvial cycle develops. Barrell's work seems to assume that the older fluvial hypothesis which explained New England's physiographic history presented all that can be said for fluvial erosional development, and it is not apparent that he considered its adequacy to explain New England's landforms according to a multicyclic theory. The several points raised in objection to the marine theory of terrace origin may be considered briefly.

THE TECTONIC REQUIREMENTS OF THE MARINE HYPOTHESIS

The diastrophic assumptions of the marine hypothesis may be questioned on two grounds: (1) they are not supported by established conclusions based on stratigraphic studies in the Atlantic coastal plain; (2) the succession of events demanded is improbable.

Barrell regarded the erosional scarps separating the terraces as the subærially reduced remains of wave-cut cliffs, which mark the limits of marine invasion and abrasion for each cycle. As

he notes,[1] each successive cycle must have been shorter in duration than the preceding, else the older terraces would have been destroyed. Although he considers the quickening of diastrophic movements a normal feature toward the close of a period of unrest, such as the Tertiary, the deposits and unconformities between the deposits of the coastal plain offer no generally accepted basis for such an assumption. Recent work in the coastal plain of Maryland has convinced the senior author that the break between the Eocene and Miocene epochs of deposition was of far greater length than that between the Cretaceous and Eocene. The recent shift in opinion with regard to the stratigraphic boundary between the Cretaceous and Eocene gives further support to this belief.[2] If this is the case, the Cretaceous terrace, or terraces, in New England would have been relatively narrow and would have been destroyed during the longer Oligocene cycle. But Barrell assigns the two oldest terraces—the Becket and the Canaan—to the Cretaceous, notwithstanding the fact that each is areally much more extensive than the single level referred to the Oligocene. Although it may be granted that diastrophic movements have been more frequent since the Pliocene, there is no reason to believe, so far as the stratigraphic record indicates, that the period between each was progressively shorter. Data are not sufficiently precise, however, to warrant the pursuit of the subject.

The diastrophic needs of Barrell's hypothesis appear unreasonable when it is recalled that (1) the time interval between each successive uplift since the Cretaceous had to be progressively shorter; (2) every uplift had to be followed by a long period of comparative quiescence while fluvial dissection took place; (3) each cycle of fluvial denudation had to be terminated by depression to permit marine modification. That this rhythmic succession of events could recur at a quickening tempo eleven different times is far too precarious an assumption to serve as the foundation of a theory, unless the assumption is supported by stratigraphic evidence.

In contrast, a fluvial explanation of New England's terraces is not hampered by any such diastrophic requirements, for the geographic limits of a fluvial surface are not conditioned by the persistence of the baselevel with respect to which it was formed. This fact seems often to be overlooked. At a given baselevel erosional development proceeds headwork, and a peneplane is produced, not simultaneously over the entire surface of the region undergoing degradation, but progressively by slow headward ex-

[1] Barrell, Joseph, *op. cit.*, pp. 361-362.

[2] Cook, C. W., and Stephenson, L. W., The Eocene age of the supposed late Upper Cretaceous greensand marls of New Jersey, Jour. of Geol., Vol. XXXVI, No. 2, 1928, pp. 139-148.

tension. At any given time in an advanced stage of the cycle, a peneplane will be found to grade inland into old forms, which in turn will shade into mature forms; these will give way to youthful topography, beyond which denudation to the current baselevel will not have taken place. If vertical uplift occurs and a new cycle begins, degradation proceeds not upon the whole surface at once, but only at the new coastline. It, too, must work slowly headward, and meanwhile fluvial erosion on the upraised level goes on unaffected, without reference to the new baselevel of erosion and without appreciable modification in rate. The peneplane and the less advanced fluvial forms at its inland limits are pushed headward, ending in a retreating erosional scarp. The retreat of the scarp at the inland margin of the older level is somewhat slower than the headward extension of erosional forms developing at the new baselevel because of the smaller volumes of the streams working upon the higher surface. With additional uplifts and the inauguration of new cycles work goes on uninterrupted upon the old levels, each terrace continuing to develop at a diminishing rate. The result is that, whatever the duration of a cycle, under ideal conditions older terraces can never be destroyed, save by complete peneplanation. On the contrary, they are self-perpetuating forms which eternally retreat beyond the limits of ensuing and pursuing cyclical levels. To speak of a fluvial cycle of erosion as being interrupted by uplift is a peculiar inaccuracy of expression which is too often taken literally. Unless strong warping or folding occurs, no cycle of erosion is entirely interrupted until, ideally, all topographic elements have been reduced with reference to it.

This broad generalization requires qualification which cannot be accorded space in the present article. Naturally the operation of the principle is modified by innumerable factors, of which differential rock resistance and geologic structure are especially noteworthy. Tilting and differential movement will produce qualifying effects. Gradation to later baselevels will proceed most rapidly and farthest along the major streams, and it is usual to find in their courses discordances of gradient which roughly coincide with the topographic unconformities between associated erosional levels. If rejuvenation occurs before a cycle is far advanced, rapid gradation along the large rivers may lead to the development at the new level of narrow terraces which interfinger with the older terraces. In such a case lateral planation of the latter practically ceases. After a series of cycles, it is usual to find several relatively narrow, fluvially planed terraces persisting toward the major stream-heads well beyond the limits of regional planation; and as a rule they are small, crowded, and sharply differentiated. Much of central Vermont occupies a

stream-head position and so affords an ideal area for studying and distinguishing the terraces of New England. Here several terraces formed during successive cycles are in proximity, whereas in southern New England the equivalent surfaces are of such low comparative relief and are geographically so extensive, that only a minute analysis can differentiate them. In many north-south valleys, however, glaciation has dealt none too kindly with the erosional terraces, and actual conditions fall far short of the ideal case described; but in other situations stream gradients, valley slopes, and uplands have a composite character which bespeaks their cyclical origin.

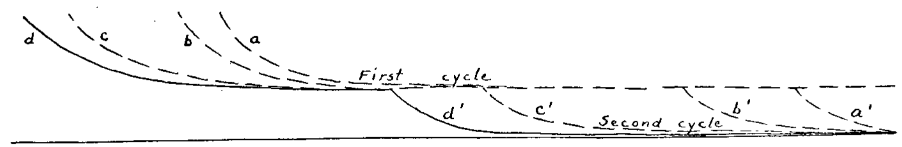

FIGURE 49.—Fluvial profile development in the second cycle.

The development of a series of essentially horizontal, banded, or belted peneplanes and terraces as the normal outcome of a succession of intermittent uplifts is a feature which has not been accorded adequate recognition. Barrell, for example, writes on this subject as follows: "Let the conditions for recording baselevels on the Connecticut upland be contrasted with those of interior regions far removed from the sea. In the latter, the rivers would keep on at their old grade even after renewed uplift until headward erosion proceeding from the sea had had time to reach the interior region. If the movement of uplift were 200 feet the steepening of the river grade during downward and headward cutting would cause, at a certain distance inland, the new grade to be only 100 feet below the old, and near the headwaters the influence of the new movement would completely disappear. Thus the stages of crustal movement are undifferentiated and become additive in a continental interior: . . . . The outer slopes of the continent, therefore, are much better adapted than the interior for a study of detailed changes in baselevel."[1]

This view, which is still widely held, cannot be supported either on theoretical grounds or by concrete examples. The manner in which the fluvial profile develops may be visualized from Figure 49, in which a and a', b and b', c and c', and d and d' represent contemporaneous positions of the profiles of the first and second cycle gradients in progressive stages of the second cycle. Uplift cannot result in degradation of the first cycle gradient, because there have been no changes in stream volume, velocity, or

[1] Barrell, Joseph, *op. cit.*, pp. 250-251.

load; and degradation occurs only in response to changes in these factors. It can likewise be demonstrated that, even with moderate tilting, first and second cycle gradients can never merge, or produce "additive" results, provided there is vertical uplift at the coastline. Barrell has thus ruled out consideration of the fluvial origin of New England's levels on a false premise.

THE RELATION BETWEEN FLUVIAL AND MARINE EROSION

Barrell stresses the opinion that, prior to marine modification by submergence, each level was reduced fluvially to a condition of late maturity or old age.[1] Yet the present state of preservation of even the oldest terraces makes it necessary to believe that the amount of fluvial denudation which has occurred since wave-planation has been negligible, although the period of exposure has in most cases been far longer than the period of genesis.

Unfortunately Barrell left unfinished specific considerations of the extent of fluvial erosion which preceded each invasion of the sea, but he believed that the amount was great. In fact, he suggests that marine abrasion of the interfluvial ridges may have been accomplished by submergence to the extent of 200 feet, the average vertical interval between the terraces.[2] The suggestion requires a long period of fluvial dissection for the formation of broad valleys deep enough to undergo the postulated amount of submergence. This method of marine terracing is exhibited on a small scale along the margins of Chesapeake Bay, but it is to be doubted that the much older terraces in New England could have been carved out of resistant metamorphic rocks in the same manner. Furthermore, the distributions and characteristics of the terraces in Vermont and Massachusetts furnish no reason to believe that negative movements of the magnitude which this suggestion demands varied the succession of positive uplifts, which characterized New England's tectonic history. The Pleistocene epoch of submergence constitutes the only determinable exception.

The marine theory assumes that the shore-forms carved by waves in the course of each epoch of submergence have endured, notwithstanding vigorous subærial attack since their abandonment by the sea. It admits profound modification, but it is highly improbable that the marine erosional features of the older terraces, impressed during brief incursions of the sea, could have escaped complete destruction in the infinitely long lapse of time since sea-withdrawal. The fact is, however, that the erosional features associated with the terraces, such as topographic unconformities, graded and composite slopes, composite river gradients, etc., have persisted and still exist as conspicuous physiographic elements. Their arrangement is largely in accord with the drainage pattern and obviously always has been. It was shown above that the topographic forms produced in the course of a fluvial cycle are capable of persisting because, within certain limits, they are perpetuated by the continued operation of the processes that formed them. The inference seems obvious. The persistence of the terraces and of the scarps separating them, and their continued development according to a fluvial pattern are facts which preclude their marine origin, and which preclude the possibility that lasting marine modifications were made upon them at any time in their history.

[1] Barrell, Joseph, *idem*, pp. 233-234; 422-426.
[2] *Idem*, p. 360.

THE OCEAN AS AN AGENT OF EROSION

As ultimately qualified to apply to New England's terraces, Barrell's hypothesis of marine abrasion involves only limited modification of greatly reduced fluvial surfaces and interfluvial ridges during short periods of subsidence. He ascribes comparatively little of the actual work of reduction to marine processes, but leaves his readers to judge the amount of wave abrasion which may have gone on upon the seaward portion of each terrace. It is to be assumed, however, from the space he devotes to proving that marine planation is capable of fashioning broad erosional benches on stationary coastlines, that he ascribed a place of considerable importance to the method, even as it affected New England. It seems pertinent, therefore, to raise in this and the two following sections several questions regarding the marine cycle, all of which have direct, if not vital, bearing upon the interpretation of New England's erosional terraces. These questions are concerned with the practical and theoretical limits of marine abrasion, the development of the marine profile, and marine deposition. These subjects are interrelated, but as far as possible they will be dealt with separately.

It may be asked whether recent studies do not tend to overestimate the importance and efficacy of marine abrasion as a means of forming extensive erosional planes. No question can arise concerning the erosive power of waves working on an exposed coastline, or concerning their ability to push back such a coastline and to develop a graded marine profile with respect to wave-base. Nor is there much question as to the ability of waves and currents to modify a fluvially denuded surface exposed to their work as the result of subsidence. But to what extent can a stationary coastline be planed? The answers given are not convincing.

It has long been assumed that the width of the continental shelf bordering a land-mass is a good index of the amount of wave planation which has occurred with reference to the adjacent coast. This assumption is apparent in the belief that the broad platforms off the coasts of Greenland, Norway, Siberia, North Africa, etc., are platforms of marine abrasion.[1] They range in width from 12-170 miles; their depths at the outer margins vary from 200-1,200 feet, but average approximately 600 feet. It has also been argued from good evidence that some abrasion can be accomplished to depths of 600 feet,[2] an amount which coincides with the average depth of continental shelves at their oceanic margins, and which thus seems to lend support to the prevalent view of their marine origin. Barrell, who studied this subject from a somewhat different angle, more conservatively estimates the limit of effective wave action at 300 feet.[3]

Both Johnson and Barrell are led to conclude that waves can cut peneplanes, and that there is no practical horizontal limit to their work.[4] As the submarine platforms off the coasts of Greenland, Norway, Siberia, and North Africa cannot be used as examples, the emergent east coast of India (the Carnatic) is employed by both authors as a type case.[5] Here, as the interesting study of Cushing has shown, a strip with a maximum breadth of 40 miles has been planed by the sea. It is doubtful whether a clearer case of marine abrasion exists. Wave-cut cliffs rising from 2,000-7,000 feet above the marine plane, wave-notched monadnocks, some of which are tied by practically undisturbed bars to the old mainland, and the thinly lateritized erosional surface planing highly folded metamorphic rocks are but a few of the marine features exhibited in this region. On the northwest the plane ends against a steep wave-cut scarp which marks the edge of a high fluvial peneplane. The latter is deeply and maturely dissected by all the rivers of the southern peninsula of India, which rise near the west coast, flow eastward across the peneplane and the wave-planed Carnatic and debouch into the Bay of Bengal.

Cushing, Johnson, and Barrell assume that marine planation of a stationary coastline has here taken place, and that no other physiographic process has been involved. The writers must question both these assumptions. The reader is referred to the map, to Diagram 1 and to Figures 2, 3, and 4 of Cushing's article. One of the most outstanding features of the marine plane is the number of prominent monadnocks which rise above it, often to the elevation of the high peneplane of which they were formerly part. If

[1] Johnson, D. W., Shore Processes and Shoreline Development, pp. 228-232, John Wiley & Sons, New York, 1919.

[2] *Idem*, pp. 76-83. Here is given the most searching and exhaustive review of the evidence published.

[3] Barrell, Joseph, Rhythms and the measurements of geologic time, Bull. Geol. Soc. Amer., Vol. 28, 1917, pp. 776-782; the piedmont terraces of the Northern Appalachians, Amer. Jour. Sci., 4th ser., Vol. XLIX, 1920, pp. 349-362.

[4] Johnson, D. W., *op. cit.*, p. 238. Barrell, Joseph, The piedmont terraces of the Northern Appalachians, *op. cit.*, p. 351.

[5] Cushing, S. W., The east coast of India, Amer. Geog. Soc. Bull. 45, 1913, pp. 81-92.

the distribution of these monadnocks is studied, it is at once seen that they are most numerous and most closely spaced in those portions of the Carnatic which are not crossed by large streams from the interior. Their interfluvial distribution, in brief, is that which would be expected had they been formed solely by the fluvial agencies operating in the region. If their formation were due to marine planation only, their distribution would have been independent of the drainage systems and dependent merely on lithology and structure.

Another point arises: Cushing has not made clear the relation between the plane of marine abrasion and the maturely dissected coastal plain which lies to the southeast. Deposition of the latter seems to have followed immediately upon the invasion of the sea that carved the former, and to judge from his block diagram the Carnatic is a stripped plane. This assumption is supported by the fact that monadnocks of metamorphic rock protrude through the coastal plain in the same way that they rise above the abrasion plane. From the data which Cushing has given us, it must be concluded that the period of marine planation was so short that neither the shore profile nor the shoreline was developed beyond the stage of early youth; and that even in this early stage of development the sea changed from an agent of erosion to an agent of deposition. If the sea had planed a belt thirty to forty miles wide on a stationary coastline, a mature profile and mature shore-forms might certainly be expected.

It may be concluded from this brief analysis (1) that fluvial processes had already accomplished most of the reduction in the Carnatic before marine abrasion occurred; (2) that marine abrasion took place in a short period of subsidence; (3) that it involved limited modification of the fluvial forms already present; (4) that the predominant marine work accomplished was aggradational in character.

The case of the Carnatic has been examined because it has been cited as an outstanding example of marine planation on a stationary coastline. This claim cannot be sustained. If relatively small oceanic banks, which the sea has attacked from all sides, be excepted, there are few, if any, large submerged areas which can be claimed as marine peneplanes on the basis of positive evidence. The submarine platforms associated with Porto Rico and the Virgin Islands and with the islands in the Lesser Antilles have proved to be drowned fluvial forms.[1] Johnson has demonstrated that the platform flanking the New England-Acadian shoreline is a dissected land-surface, and he presents convincing

[1] Davis, W. M., The Lesser Antilles, Amer. Geog. Soc., New York, 1926. Meyerhoff, H. A., The physiography of the Virgin Islands, Culebra, and Vieques. Scientific Survey of Porto Rico and the Virgin Islands, N. Y. Acad. Sci., Vol. IV, 1926-1927, pp. 107-119; 170-175; 198-207.

reasons for a belief that the submerged shelves in the St. Lawrence embayment and in the upper Great Lakes are in large part of similar origin.[1] These platforms are thus far the only ones which have been studied critically, and it is likely that the list will grow. The platforms off the coasts of North Africa, Madagascar, and Norway (in part), and a few completely planed oceanic banks may prove to consist partly of planes of marine abrasion, which were developed with respect to a relatively stationary wave-base. Even if these platforms are wholly marine in origin, Johnson reminds us that their oceanic margins are aggradational, and that the parts formed by marine planation are considerably narrower than their total widths. On the other hand, areas which have been recently elevated above the sea, which include, among many others, the east coast of India, sections of the Atlantic and the Gulf coasts of the United States, the western part of the St. Lawrence lowland, and much of the Arctic coast of Canada, show that, except for important but superficial marginal abrasion, the work of the sea has been primarily aggradational; its erosive work has been subordinate.

At the present time, the case for marine planation of broad terraces along stationary coasts rests upon a very few examples, including oceanic islands and limited sections of continental shelves, most of which have not been studied critically. On the other hand, the broad areas of the earth which have been raised above sealevel, and which have not been too deeply dissected since emergence strongly suggest that the ocean is predominantly an aggradational agent, and that deposition goes on in many instances even where shoreline and marine profile are young. The theory of marine abrasion so conspicuously lacks convincing factual support that its premises may justly be called into question. If the theory be sound, some explanation of the prevalence of aggradational features must be given.

A COMPARISON OF MARINE AND FLUVIAL PROFILES

The analogies between the marine profile and the fluvial profile are close. Both have forms that are concave upward, steepening in grade toward their upper limits. Both are divisible into two sections: the profile of abrasion in their upper reaches where degradation is the dominant process, and the profile of aggradation in their lower reaches, where terrace or delta formation takes place. The most obvious point of difference—in large part a superficial one—is the linear character of the fluvial profile, which is usually limited to the representation of stream gradients, and the regional character of the marine profile, which in general represents a cross-section drawn normal to the coast at any point. A more fundamental difference between the two is found in the fact that the fluvial profile is flatter than the marine profile in post-youth stages of development. This follows from the consideration that the fluvial profile ultimately has few obstacles to hinder its development and extension, whereas the marine profile must develop against the static resistance of water and the less calculable counter-forces provided by waves of translation. In the aggradational sections of both profiles the difference in gradient is slight; in the destructional portions it is appreciable and important.

[1] Johnson, D. W., The New England-Acadian shoreline, pp. 211-234; 264-296; 405-415; John Wiley & Sons, New York, 1925.
Paysages et problemes geographiques de la terre Americaine, pp. 151-172, Payot, Paris, 1927.

It will at once be conceded that, in the normal development of the fluvial profile, the degraded section will ultimately be aggraded. The lengthening of a river's course by delta building necessitates headward aggradation, in order that the stream may remain at grade. In the process, as is well known, the profile of degradation is built up, as well as the profile of aggradation. If subsidence of the land surface occurs, thereby raising the baselevel of erosion, aggradation extends still farther headward, but the essential features of gradient development are not otherwise affected. In the process of stream gradation sealevel serves as a control which compels penultimate aggradation on stationary and sinking surfaces.

Wave-base governs gradation of the marine profile as rigidly as sealevel controls the process in streams. Johnson regards a depth of 600 feet below sealevel as an approximate maximum for wave-base, but Barrell reduces the figure to 300 feet. Both writers agree that the depth varies on different coasts with local conditions. Whatever position wave-base may have in a given case, it rigidly controls the entire development of the marine profile. The profile of abrasion cannot be torn down below it; the profile of aggradation will be built up and extended with reference to it. Inasmuch as the marine profile must remain in equilibrium, the forward building of the wave-built terrace requires aggradation of the entire profile in exactly the same way that delta building compels aggradation of the fluvial gradient; hence deposition must occur on the profile of abrasion. In the case of streams submergence is followed by more extensive aggradation; similarly, the raising of wave-base by submergence of the adjacent coastline requires aggradation of the entire profile, except at the new shoreline.

Theoretically, if there is no change in sealevel, aggradation of both profiles will proceed until all areas that are not in equilibrium with respect to baselevel, or wave-base are reduced and graded. Aggradation will then cease, and degradation will begin and will proceed until, in the one case, the ideal of base-level is attained; in the other, that of wave-base. In both instances the process will involve excavation and lowering of the profile of abrasion, and in the ultimate stage of development the destructional and constructional sections of the profile will have approximately the same geographic positions as they had when initially formed. The penultimate stages of both marine and fluvial cycles are so greatly protracted, that, as every textbook in general geology and physiography emphasizes, the ultimate stage is never reached. In the marine cycle the ultimate stage cannot begin until the land-mass is reduced to sealevel, so that waves can work upon every portion of it. Except for relatively small oceanic islands, it is doubtful if any large land area has been reduced to this extent at any time in geologic history. It is to be expected, therefore, that, whenever the marine cycle has been interrupted, the aggradational period of its history will not have been passed, and that marine deposits will characterize the wave-formed surface. These deposits are not to be confused with the veneer of material which has come temporarily to rest on higher portions of the abrasion platform. Although they may be much alike in physical characteristics, these two types of deposits must be differentiated by their contrasted relationships in the profile of equilibrium.

The view of the development of the marine cycle presented above is open to attack on several theoretical grounds, which cannot be considered in this report. It is Johnson's opinion that aggradation plays no part in the normal development of the profile of abrasion, except as a temporary feature in its early stages.[1] Barrell as a stratigrapher recognized the importance of marine deposition, but as a physiographer he assigned it no place in the marine cycle. His inconsistency epitomizes the clash between physiographic theory and stratigraphic fact, and in the last analysis a theory which ignores the vast body of facts which stratigraphy offers is on precarious ground. The original structures, lithologic characteristics, and faunal contents of marine clastic sediments show that they have in general accumulated well within the limits of moderate wave action both in epeiric and epicontinental seas. Few of these deposits can be interpreted as the thin veneer which at all times covers the abrasion platform. The vast majority of them cannot be regarded as deposits of the wave-built terrace. Many of them, it is true, were deposited on a subsiding sea-bottom, and under conditions of subsidence aggradation must occur. A substantial number of formations, however, are known

[1] Johnson, D. W., Shore processes and shoreline development, pp. 224-228. Note especially the paragraph on pp. 226-228.

from paleogeographic evidence to have accumulated in seas with relatively stationary shorelines. These deposits surely must have formed as normal aggradational features in the development of the marine profile, else their existence cannot be explained. The writers believe, therefore, that aggradation of the marine profile in the normal course of its development must be accepted as a principle, which appears to be supported by the stratigraphic record, and which in turn affords the only explanation of many clastic marine deposits formed in the past.

The principles of marine profile development apply to the case of New England in two important ways. As noted above, the marine profile of abrasion is normally steeper than the corresponding fluvial profile in mature and post-mature stages. The declivities of marine gradients may be gauged from data gathered by Barrell,[1] but his figures for sea-depths at given distances from the shoreline cannot discriminate between the profile of abrasion and the profile of deposition. The angle of declivity near the coast may be assumed, however, to approximate the slope of the abrasion profile. In the first mile the amount is 45 feet; in the second, 21 feet. As his figures are based on actual cases, it is probable that the reduction in the angle of slope beyond two miles is in part due to aggradation. Yet from the shoreline to a distance of five miles, the average declivity of submarine platforms is 19 feet per mile.

According to the marine hypothesis of origin, all the terraces of New England must have occupied marginal positions with respect to the coast. Even if it be agreed that wave planation merely modified the fluvial surface, the angle of gradient would not be affected,[2] and it is to be expected that the surface of each terrace, if it be marine in origin, would slope not less than fifteen feet per mile for the first five miles. But this is not the case. The slopes "of the terraces from the Becket to the Prospect inclusive are essentially parallel and average seven feet per mile, that of the Towantic is four feet, whereas for the lower terraces it is two feet."[3] On the terraces of New England, moreover, aggradational features are not present to lessen the angle of declivity, as is probably the case on the platforms which furnished data for Barrell's figures. Their low gradients are thus at variance with the requirements of the marine hypothesis; but a final conclusion must be withheld until more data on marine and fluvial profiles are made available.

[1] Barrell, Joseph, Rhythms and the measurements of geologic time, *op. cit.*, pp. 779-780; the piedmont terraces of the Northern Appalachians, *op. cit.*, pp. 353-354.
[2] Barrell, Joseph, The piedmont terraces of the Northern Appalachians, *op. cit.*, pp. 357-362.
[3] *Idem*, p. 416.

THE ABSENCE OF MARINE DEPOSITS

The second way in which the principles of marine profile development apply to the erosional history of New England relates to deposition. Even if it be not admitted that aggradation goes on to a moderate degree in the normal development of the marine profile until the penultimate stage is passed, it cannot be denied that aggradation is concomitant upon subsidence. Barrell believed that subsidence was responsible for the invasions of the sea which caused marine modification of the pre-existent fluvial landforms; hence a moderate amount of deposition must have taken place during each epoch of submergence.

It may be agreed immediately that marine deposits left upon the higher and older terraces would have been destroyed by subærial erosion. But it is impossible to believe that every vestige of marine material would have been removed from the younger and lower terraces, especially when deposits of considerable thickness—perhaps as thick as 200 feet—must have accumulated in the deep, drowned valleys between the interfluvial ridges.[1] The epoch of post-glacial submergence is proved by estuarine deposits of considerable extent; yet, according to the marine hypothesis, this was one of the briefest and, so far as its erosional record is concerned, one of the least conclusive of the periods of drowning. To the writers it seems impossible to accept the hypothesis without similar evidence of Pliocene deposits. Glaciation can be held responsible for many acts of destruction but surely not for the complete obliteration of thick formations in protected valleys, especially in Connecticut where the carrying power of the continental glacier was already heavily taxed, and where it was an agent of deposition rather than of erosion.

The strongest argument in favor of the marine origin of the terraces in the Northern Appalachians rests upon the many cases of stream superposition across resistant ridges and hard-rock areas, which, it is assumed, could not have been reduced during a fluvial cycle. It seems probable that Barrell underestimated several factors, among which may be mentioned: (1) the adequacy of lateral planation on river floodplains to level hard-rock ridges on the valley margins; (2) the indefinite continuation of gullying and sapping with reference to each erosional plane as long after uplift as any appreciable portion of the original surface remains; (3) the potency of stream capture after much of the country has been reduced to a lower erosional plane. It must be granted, however, that these factors are inadequate to explain many cases of superposition, to effect which actual burial of monadnock ridges must have occurred. But a cover of marine

[1] Barrell, Joseph, *op. cit.*, pp. 348, 360, 411-412.

materials would have been no more effective than the veneer of alluvium which would have been deposited on the floodplains during advanced stages of the fluvial cycle. In Vermont and western Massachusetts most, if not all, of the principal tributaries of the Connecticut are superimposed streams for distances ranging up to twenty miles headward from their mouths. As will be shown in the concluding section of this paper, the relationship between mainstream, tributaries, and terraces indicates that superposition occurred with reference to the Connecticut floodplain in one of the early cycles of erosion, and that a marine interpretation of the facts is untenable.

In support of his theory Barrell cites the discovery of waterworn gravels, which were found in several inter-stream localities on two of the terraces in Maryland.[1] Unfortunately, as Johnson has pointed out, the gravels in question may be of stream origin, and their significance cannot, therefore, be interpreted. Criteria for the differentiation of river and littoral gravels are not firmly established, and at the present time deposits of this kind lend as much support to the fluvial hypothesis as to the marine.

This review of the principles which govern the development of marine and fluvial cycles has attempted to show (1) that a theory which calls for marine planation of large surfaces is but weakly supported by an appeal to facts; (2) that, judged on theoretical and factual grounds, the application of such a theory to New England cannot be sustained; and (3) that, so far as firmly established criteria permit an opinion, they favor the fluvial explanation of New England's landforms. Perhaps the review has demonstrated more convincingly the uncertain status of fundamental principles and the inadequacy of present information to serve as a basis for sound conclusions. It is indeed fortunate that the fluvial interpretation of New England's erosional terraces rests upon more satisfactory and positive evidence.

THE FLUVIAL CHARACTERISTICS OF NEW ENGLAND'S EROSIONAL LANDFORMS

The preceding discussion has brought out a number of points concerning the terraces of New England which may profitably be summarized. Barrell stressed the fluvial pattern of the terraces and of their marginal scarps in Connecticut and Massachusetts. This feature is equally prominent in Vermont and seems to characterize the entire series of erosional levels that extends from Long Island Sound to Canada. The terraces in Connecticut are flat-topped, those in Massachusetts, gently rounded, whereas the levels of northern New England display moderate amounts of relief. The change is gradational and appears to be attributable to

[1] Barrell, Joseph, *op. cit.*, pp. 426-428.

the better state of preservation of the younger terraces in Connecticut and to their greater degree of initial perfection as a consequence of their proximity to the sea. The remoteness of western Massachusetts and central Vermont and the greater age of most of the terraces in this part of New England are factors which favored less initial perfection and poorer preservation. The gradational character of the change and the similarity of the terraces in all other respects preclude the likelihood of a genetic difference between those in the north and those in the south. A single method of origin must be postulated for all the levels of the entire region, if their characteristics have been correctly described.

The fluvial pattern of the terraces is plainly not a feature which has been imparted to them by erosion since their formation, and this fact was emphasized by Barrell, who regarded their fluvial form as the outcome of subærial dissection which antedated marine modification. This view requires a complicated tectonic history, which effectively scouts credulity when it is found that the wave work done during each successive epoch of submergence stopped short at the same point; namely, before the postulated shorelines had passed beyond the initial stage of development. The scarps between the terraces protrude southward and southeastward in pointed, prong-like spurs; they retreat upstream along the valleys, usually for many miles, before they wedge out at the stream channels. Scarps of this type are not wave-cut cliffs; they are unmodified fluvial scarps, and none of those which the writers have studied in Massachuestts and Vermont show a sign of marine modification at the spur points, which, had they formed peninsulas extending for miles into the sea, would have been conspicuous targets for wave attack. The possibility that an oscillating strandline brought the sea temporarily over part or all of some of the fluvial terraces cannot be denied; but it is difficult to believe, if most of them were completely covered and modified by transgressing seas, that prominent fluvial spurs completely escaped modification in every period of submergence.

In the last analysis an hypothesis must rest upon positive evidence and cannot depend for its support on negative criticism of a rival theory. Thus in arguing for the fluvial origin of the erosional terraces of New England, the authors feel that their case rests not upon the improbability of a marine hypothesis, but upon the clear fluvial cast of the terraces which they have examined in western Massachusetts, in southeastern, central, and northern Vermont, and in southeastern New York. In the concluding section of the present paper attention must, therefore, be directed to a consideration of the characteristics of the terraces

which have been studied in detail in Vermont and Massachusetts. The authors have not examined any of the levels in Connecticut, but their work has overlapped Barrell's in western Massachusetts. As noted above, the one point of difference between the terraces in Connecticut and those in Massachusetts is a gradational difference which appears to be related to initial perfection and subsequent modification, rather than to genetic factors. Unless new definitive evidence to the contrary be found, it seems likely that the erosional levels of Connecticut must, like those in Massachusetts and Vermont, be considered fluvial in origin.

Before detailed consideration is given to the erosional features of Vermont, it may be well to recapitulate the positive evidence thus far adduced in support of a fluvial theory of genesis. Such a theory is favored by (1) the conformance of terrace pattern, profile, and cross-section with the theoretical arrangement of cyclical terraces in river systems; (2) the necessity of ascribing a large part of the work of denudation to antecedent fluvial processes, whatever theory is adopted; (3) the adequacy of fluvial planation to carve broad erosional terraces along large streams; (4) the low regional profiles of the terraces, which is more typical of fluvial gradients than of marine profiles of abrasion.

THE EROSIONAL TERRACES OF VERMONT

METHODS OF STUDY

The validity of conclusions depends as much on the field and laboratory procedure employed in making observations as on sound reasoning from the observations made. The following description of the erosional forms of Vermont may be appropriately prefaced, therefore, by an exposition of methods.

It was felt that impartial field observations are difficult to make if conclusions have already been reached on the basis of detailed laboratory studies. The writers decided, therefore, to utilize profiles and maps to corroborate conclusions drawn from field data, hence preliminary map study and profile work was designed merely for the purpose of selecting field routes. It was not until a complete set of field data had been collected that systematic profile and map study was undertaken. Here, too, the need for caution was so strongly felt that independent interpretations were made on the basis of two sets of profiles prepared separately by each of the authors. The almost exact agreement between the two interpretations made from the profiles, on the one hand, and between field and laboratory determinations on the other has supplied a measure of confidence in the conclusions proffered.

The field work involved five trips, varying in duration from four to eighteen days, chiefly in Windham, Windsor, Orleans, and Lamoille counties, Vermont, and in Franklin and Berkshire counties, Massachusetts. Numerous shorter trips were also made to localities in western and central Massachusetts, western New Hampshire, and eastern New York; but only the area embraced between the Taconic section and Deerfield, Connecticut, and White rivers in Windham (Vt.), Windsor (Vt.), and northern Franklin (Mass.) counties was given intensive study. In general this area was traversed from east to west, for the terraces are associated chiefly with the major north-south streams, and traverses run normal to their courses facilitated correlation of the levels associated with them. It was found expedient, however, to trace some of the terraces northward along the different rivers and to study the Deerfield River and West River systems from source to mouth as separate, but typical units.

Maps of four of the quadrangles in the district which was studied intensively have not been published; but, thanks to the courtesy of Professor G. H. Perkins, proof sheets of two of these were made available. The remaining two quadrangles were covered by a closely spaced network of traverses, in the course of which observations were carefully controlled by barometric readings. The results obtained checked accurately with those which were guided by topographic maps, but the writers feel that the observations made in the unmapped quadrangles are merely qualitative.

In the field, data were sought on the following points:

(1) The number of the terraces present.
 (a) Within the region as a whole.
 (b) Within the limits of each traverse.
(2) Characteristics of the terraces.
 (a) Stage of development reached at time of origin.
 (b) Past and present relation to streams.
 (c) Correlation between wind-gaps, composite stream gradients, etc., and erosional levels.
 (d) Nature of the terrace boundaries.
 (e) Dissection and modification since time of origin.
(3) Characteristics of erosional scarps.
 (a) In relation to individual terraces.
 (b) In relation to lithology and structure.
(4) Origin of the superimposed streams.

Some attention was also given to possible changes in drainage during the physiographic development of the region and to the possibility of relative diastrophic changes in the positions and gradients of the terraces. Manifestly information on all these

subjects could not be obtained from every part of the region studied, and on some of them additional data are necessary.

At first the work was hampered by a prejudice in favor of a small number of erosional levels, but the complete failure of this view to explain any of the field phenomena led to its early abandonment. Yet it was not until the last four weeks of field study that the authors developed complete freedom from a tendency to merge erosional surfaces that proved to be wholly distinct. Field evidence established the presence of all the terraces enumerated in Table I, except the two lowest levels, which were identified by means of map and profile work after the field studies were completed. As already noted, some doubt was felt about the validity of the levels identified at 3,000-3,200 feet, 1,820-1,920 feet, and 1,180-1,240 feet; but there was enough field evidence to postulate their existence, before corroborative laboratory analysis was begun.

Laboratory study was based on the topographic maps published by the United States Geological Survey for the following quadrangles (Figure 44): (1) Warwick,[1] (2) Greenfield, (3) Hawley, (4) Greylock, (5) Keene, (6) Brattleboro, (7) Wilmington, (8) Bennington, (9) Bellows Falls (proof sheet), (10) Londonderry, (11) Equinox, (12) Claremont (proof sheet), (13) Wallingford, (14) Pawlet, (15) Hanover, (16) Woodstock, (17) Rutland, (19) Strafford, (20) Randolph, (21) Rochester, (22) Brandon, (23) Barre, (24) Lincoln Mountain, and (25) Middlebury. Maps of the Bellows Falls and Claremont quadrangles were available only in proof sheets drawn to a scale of 1:48,000. In the preparation of profiles time was not available to reduce these two maps to the common scale of 1:62,500 for the purpose of accurate comparison; hence the same vertical scale adopted for the balance of the profiles was employed, with satisfactory results, notwithstanding the larger horizontal scale. When the maps of these two quadrangles and of the two quadrangles immediately west of them are printed, they will yield some of the best and most interesting sections across the terraces. An almost complete series of levels is found within them, and in addition, the Claremont quadrangle contains the strikingly anomalous feature of Ascutney Mountain, which rises nearly 3,000 feet above the river level, using comparatively low terraces as a base. The mountain consists of an isolated mass of intrusive rocks, which have demonstrated in spectacular fashion their superior resistance as compared with the surrounding metamorphics.[2]

[1] The number preceding each name is the one assigned to the quadrangle in the location map (Figure 44).
[2] Daly, R. A., The geology of Ascutney Mountain, Vermont, U. S. G. S., Bull. 209, 1903.

Exclusive of numerous special problems which have constantly arisen, laboratory study has been concerned chiefly with (1) construction of a comprehensive set of systematic profiles; (2) plotting of the gradients of the major streams; (3) preparation of a map to show distribution of the terraces. The preparation of a map which can lay any claim to accuracy has proved too much of a task for inclusion in this article, but it is hoped that it will be completed as the study is continued. The analysis of stream gradients is not finished, but those streams which have been profiled have shown by their composite character the intimate relation that exists between gradient and terrace development. As a criterion by which the existence of cyclical levels can be conclusively proved or disproved, little can be claimed for the use of stream gradients in a glaciated country, unless each case is carefully studied in the field. Without field verification, however, they may serve as contributive evidence. Illustrations of their utility in northern New England will be cited on following pages, but one case may be mentioned here. Field study established the cyclical origin of Shelburne Falls on Deerfield River. The fact that waterfalls and rapids occur in Millers, West, White, and Connecticut rivers at the same elevation is in itself sufficient evidence for the recognition of the New Canaan cycle, without the added proof of benches.

The plotting of profiles that represent accurately the degradational features of the region studied offered several perplexing problems, some of which have not been ideally solved. The choice of horizontal scale was automatically settled at 1:62,500 by the use of the topographic maps of the United States Geological Survey as a base. The choice of vertical scale was a more delicate matter. The erosional levels to be studied are far from perfect. Relief of 100 feet or more is common, even in areas where all the elements are graded to the same erosion base, and in many sections monadnocks rise above the terraces to the elevation of the next older level. In numerous areas along small streams or in interfluvial positions, the evidence for a cycle consists of slopes graded to a definite base, for the true erosional planes formed during the same cycle may be restricted to localities marginal to the large streams, which as a rule are now entrenched below them. In consequence the employment of a vertical scale as highly exaggerated as that used by Barrell and Lobeck[1] so steepened the graded slopes that they were scarcely to be distinguished from topographic unconformities. The writers experimented briefly with this scale, and also had the privilege of examining a set of profiles of the Green Mountains belt in which it had been employed by Miss Pond. It was

[1] One inch = 200 feet, or approximately 26 times the horizontal.

promptly agreed that the scale was of little value in a study of the landforms of northern New England. After some trial and error a vertical exaggeration of 5.3x (one inch = 1,000 feet) was chosen. Admittedly it is not always the best in a given case, but its general satisfactoriness, its convenience, and the need for a uniform scale in all sections led to its adoption in the profile work. In plotting stream gradients, on the other hand, this scale yielded poor results, and the scale of one inch = 200 feet proved so much more satisfactory that it was used exclusively.

The utility of various types of profiles demanded still more careful consideration. As a basis for interpreting dissected erosional uplands, the linear, or vertical plane, profile has been condemned because it emphasizes dissection and minimizes upland development, and because choice of the section involves a subjective element which is eliminated by the representation of broader belts of country. Granted the general truth of these two contentions, several points may be advanced in favor of the use of linear profiles under some circumstances: If a terraced river valley is to be profiled in a direction normal to its trend, the linear profile is the only accurate and objective means of representation. A single profile of this type will prove little; but if a series of such profiles, systematically selected, reveal the same features, inferences may be safely drawn. A projected or zonal profile across the same valley will inevitably confuse the topographic elements by taking into account the bends in the river, in the terraces, and in the valley walls, and will ultimately involve more of the subjective element in choosing the features to be shown or omitted than is involved in locating a linear profile. Without the subjective element a zonal profile of the terraced valley cannot show the essential physiographic forms.

On the other hand, if a series of terraces flanking a river is to be represented in a section paralleling the course of the stream, it is doubtful whether projected profiles of the Barrell type can be improved upon, despite the claims made for variations on his method. In such a situation the elements to be shown are the rising steps in the topography; foreground and background are essential. Such profiles may well utilize the stream gradient as a base line, upon which successive tiers of terraces can be constructed, until all between the river channel and the drainage divide have been included. This type of profile should be used also for sections paralleling a coastline from which broad benches rise inland like a flight of steps. As Barrell points out, the use of this method involves careful selection of direction, so that the higher topographic elements form the background; but inasmuch as this direction is determined by nature the selection can hardly be called subjective. Projected profiles possess one source of danger: As slopes normal to the section cannot be represented, it is possible to interpret a simple, rising, but dissected surface as a series of low terraces. Longitudinal profiles must, therefore, be checked carefully against transverse profiles, if errors of this kind are to be avoided. In the present study a series of projected profiles which employ each of the major streams as a base has been found particularly useful in determining the development of terraces along each of the rivers. The series proved of great value in correlating the terraces in different stream systems and offered many interesting side-lights on the influence of geologic structure and the effects of glaciation.

Zonal profiles[1] of the type used in Lobeck's New Hampshire studies are best adapted to represent by projection the skyline of a simple upland. This method of profiling is relatively inflexible and ordinarily cannot be employed for composite surfaces in which the elements overlap or trend in a direction parallel with the section. The depth of the section is severely limited, for if too wide a belt of country is comprehended, monadnocks may become more conspicuous than the upland above which they rise; if the zone is too narrow, dissection receives undue emphasis. In practice the profiles are drawn from zones, or strips, of country ranging from two to five miles in width. Each may consist merely of a line passing through the highest points present in the entire zone; or of a median linear profile, above and below which maximum and minimum variations in altitude are represented by dots or, for specific forms, by dotted lines; or of a line representing the average or mean elevation of the landform to be represented, and omitting features which rise distinctly above, or fall distinctly below it. In any case, whatever feature is chosen for representation, all other features suffer partial or complete elimination. Dotting in monadnocks and valleys helps materially, but single dots to show variations in altitude on the upland aid little in the task of visualizing the distribution and relation of valleys and eminences. The method fails completely to differentiate intermediate levels, which may parallel the section; and by eliminating them and simplifying a composite surface, it can lead to wholly erroneous interpretations. On the other hand, if zonal profiles are drawn normal to the trend of terraces, they are unquestionably as effective as other means of representation and have the double advantage of being systematic and simple.

[1] The term "projected" is generally applied to profiles of this type, for in their construction a zone is projected into a line, which forms the profile. The writers feel, however, that the term "projected" has been preempted by Barrell and so can be applied only to those profiles which project specific forms on a plane by superposition. They will, therefore, employ the term "zonal" for the type used by Lobeck.

For the purpose of corroborating and systematizing the tentative conclusions drawn on the basis of field studies, a set of forty-two east-west zonal profiles, varying in length from twenty to forty miles, was prepared. They cover the entire area between Deerfield and White rivers, and extend short distances north and south of these streams. Except for the district between the Londonderry and Wallingford quadrangles and the Vermont-New Hampshire boundary, for which topographic maps have not been printed, the profiles are drawn westward from Connecticut River to the eastern border of the Taconic section. This set of systematic profiles was supplemented by a few longer ones extending from various points in New Hampshire and north-central Massachusetts westward and northwestward across the Green Mountains and the Berkshires. The prevalent trend of the terraces made north-south zonal profiles of little value. It is planned, however, as the investigation progresses, to complete the network of systematic profiles with a series from the southern to the northern limits of the region studied. In the preparation of this paper, however, the place of such a series was taken to better purpose by projected profiles along the streams.

In analyzing the erosional features of southeastern and central Vermont the writers have thus found that superior merits cannot be claimed for any one method of profiling. Each has advantages for the illustration of specific features, but all three methods combined, since they involve exaggerated, two-dimensional representation of nicely adjusted, three-dimensional forms, give at best a partial and distorted picture, which, as Davis has pertinently remarked, can too easily "lead different investigators to different results." It must be admitted, however, that, had profiles been made the sole basis for the conclusions reached in this paper, the results may have been less conclusive but not materially different. In general the authors have tried to develop the field investigations and the profile studies as independent phases of the work, so that each might serve as an effective check against the other. The profiles have thus been employed to confirm and refine the conclusions which were reached in the field. They have supplemented the latter in a number of ways, especially by making it possible to differentiate erosional levels which are separated by short vertical intervals, and which in the field were sometimes confused. They have been indispensable, also, as a means of correlating the terraces throughout the area studied intensively.

THE EROSIONAL TERRACES OF THE CONNECTICUT VALLEY

Field and laboratory studies of the landforms in north-central New England show clearly that its physiographic history has been dominated by Connecticut River. A view from any of the high monadnocks fringing the western side of the upland that stretches for fifteen to thirty miles west of the river offers conviction of this fact. Hoosac, Haystack, and Glebe Mountains and, farther north, Rochester and Braintree Mountains, all of them more than 3,000 feet high, are favorably situated monadnocks which provide unobstructed views eastward across the Connecticut upland to the White Mountains. From their summits can be seen its broad, rolling, dissected surface, and from the superior height of the vantage point which has been chosen its many irregularities appear dwarfed into unimportance. The river is not to be seen, for it is entrenched deep within the upland, which stretches eastward across New Hampshire until its surface ends, on the south, against Mount Monadnock, and, farther north, against the irregular masses of the White Mountains. From any of the peaks selected the upland appears as a broad valley lowland, 40-50 miles wide, with the Green Mountains on the one hand, the White Mountains on the other, serving as its valley walls.

The genetic relation between this broad, reduced intermontane belt and the Connecticut is clear. The river is subcentrally located within it; the planed upland parallels the river and narrows slightly—almost imperceptibly—northward. River and planed upland closely parallel the geologic structure and are in a broad sense subsequent. Comparison with the Triassic lowland in Massachusetts and Connecticut suggests itself, and surely the river was as intimately concerned with the origin of the one as with the origin of the other. The Connecticut "lowland" of northern New England, however, is not as strictly controlled by the non-resistance of underlying rocks as is the Triassic lowland; for, in the former, hard-rock formations have suffered reduction to a much greater extent than in the latter. Yet here and there a particularly stubborn mass, like Ascutney Mountain, rises high above the general level.

The panoramic view obtained from one of the high ridges at the western border of the upland tempts the observer to draw a premature conclusion: for it seems certain that the planed surface below him must be the Cretaceous peneplane, above which the monadnock ridge from which he looks rises with sharp topographic unconformity. But let him descend. If Haystack Mountain, four miles northwest of Wilmington, has been his point of vantage, he will descend into the valley of the North Branch of Deerfield River. A broad rolling upland, graded to an elevation of 2,100 feet, stretches eastward before him on both sides of the stream (Figure 50); but nearer North Branch this upland drops sharply to a smoothly graded erosional terrace

at 1,900 feet, locally as much as a mile wide both east and west of the river. Within the lower terrace North Branch is entrenched at an elevation approximately 1,600 feet; but even its valley is compound, for it is broad and open above 1,600 feet, and young where the river has begun to cut a steepened course below this altitude. About six miles east of the base of Haystack Mountain and beyond the terraces associated with North Branch he ascends Higley Hill or Hogback Mountain, and from either of these eminences he views to the east a constricted replica of the upland seen from Haystack. Now, from its compound surface he must decide whether the upland level is the one represented by the many hills approximating 1,900 feet in elevation, or the

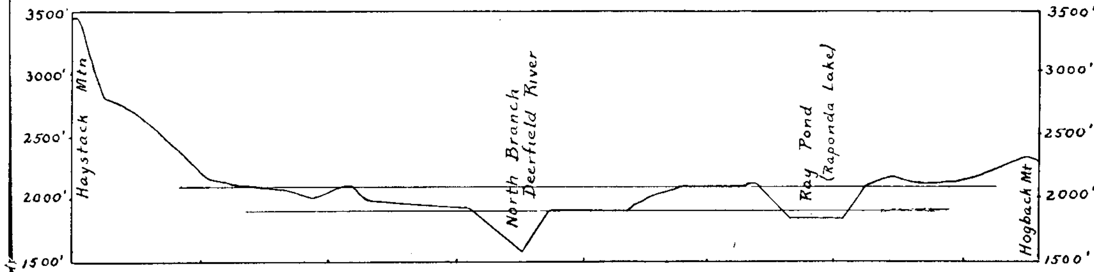

FIGURE 50.—Linear profile from Haystack Mountain to Hogback Mountain, showing development of 1,900 foot and 1,200 foot levels.

equally distinct one between the hills at 1,660 feet. As he goes eastward the latter acquires greater prominence, until at Wickopee Hill (six miles east of Higley Hill) it too vanishes (Figure 51),[1] and he looks down into a veritable lowland, 10-12 miles wide, most of which lies below 1,000 feet in altitude. The descent, however, must be made in a series of steps, first to a narrow inconclusion bench, 1,300-1,400 feet above sealevel, then to a clearer level at, or slightly above, 1,200 feet. West River confuses the impression, and he may miss a fragmentary level at 1,000 feet, but he cannot avoid the ones at 800 feet, 540 feet, 420 feet, and 260 feet, which he may encounter either in association with West or Connecticut rivers. Each terrace is separated from the other by a steep scarp, which in most instances contrasts strongly with the rounded or graded slopes that characterize the comparatively narrow benches in the seven miles between Wickopee Hill and the Connecticut.

[1] Figures 51a and 51b, zonal profiles, illustrate one weakness of this type of profile. Although it shows the step-like character of the descent from Wickopee Hill, several of the levels which are clear in the field and on the maps are partly or completely cut out by spurs that project eastward from the higher terraces.

Had he crossed the upland from any other monadnock upon its western border, his experience and his impressions would have been the same. The upland is composite. It is made of a number of levels which have been dissected to a greater or less degree. Invariably the higher ones are best developed westward in situations comparatively remote from the Connecticut, whereas in areas nearer the river, lower ones become dominant. Occasionally one

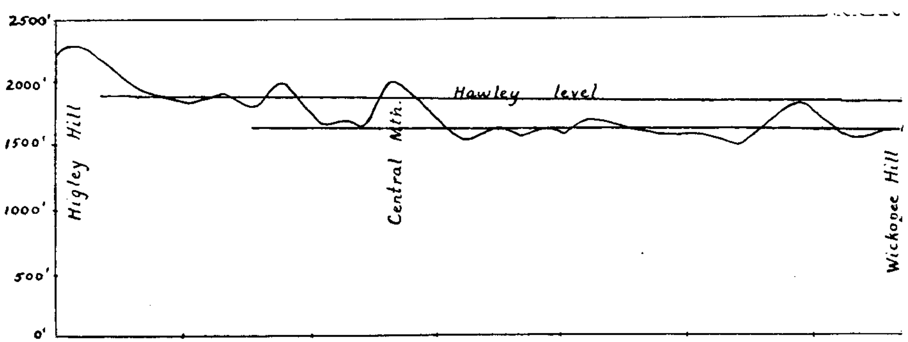

FIGURE 51a

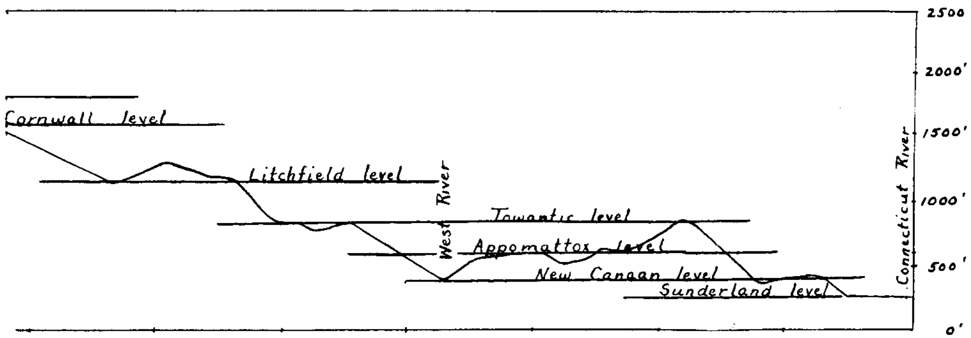

FIGURE 51b

FIGURES 51a and 51b.—Zonal profile from Higley Hill to Connecticut River.

or another of the levels ends abruptly at a resistant, structurally controlled ridge; more characteristically two or even three will form elements in a single landscape, a higher terrace being represented by a few straggling hills or sharp ridges which still linger east of the position to which the rest of the level has retreated. Lower terraces are repeated in association with the larger tributary streams, but for the most part the arrangement and development of the successively rising steps appear referable directly to the Connecticut rather than to its tributaries.

Views across the Connecticut valley into New Hampshire show clearly that the ascent from the banks of the river to the highest portions of the upland must likewise be made across a series of stair-like erosional terraces, which seem to match those in Vermont. East of the river, however, the terraces appear from a distance to be slightly more regular, less dissected, and somewhat narrower. These features suggest that they were formed on more homogeneous and more resistant rocks, which were better adapted to withsand erosional processes since each level was developed. On both sides of the river, towns and villages are naturally most numerous along the banks, where the railroad has concentrated them; but any broad view of the four- to eight-mile belt lying below 1,200 feet immediately adjacent to the Connecticut impresses on the observer the fact that many villages and some towns, like Claremont, New Hampshire, are located high above the river level on one of the erosional terraces which flank it.

A series of zonal profiles drawn from Connecticut River to the western border of the upland confirms the impression that it is composed of a number of benches which parallel the course of the river. Examination of many such profiles shows considerable irregularity of development. Here, perhaps, a resistant ridge has served as a barrier to the westward extension of some of the terraces; there, possibly, a large tributary, with reference to which analogous terraces were also planed, gives near its junction with the mainstream greater areal extent and exaggerated importance to some one erosional level. Yet, with local exceptions of this nature, the significant facts revealed by the systematic east-west zonal profiles which were drawn between Deerfield and White rivers, are (1) the persistence of all but the two lowest levels in the entire 80 miles of this section; (2) their comparative constancy in width and relative importance, except where large tributaries or special lithologic and structural features have caused local modifications in their development; (3) their almost negligible rise in elevation northward—enough, but no more than enough, for the maintenance of a low fluvial grade at the time of their formation.

The disappearance of the two lowest levels northward along the Connecticut is typical of the more common disappearance of terraces on its tributaries, and so merits description. In the northern portion of the Triassic lowland in Massachusetts the Connecticut has degraded its channel, in both the alluvial deposits formed during post-glacial submergence and the Triassic sediments, to an elevation which approximates 110 feet above sea level. It is entrenched within narrow, planed terraces, the elevation of which averages about 160-180 feet. Between Montague

City and Turners Falls the river's gradient is steepened, and within the space of six miles it rises to a level of 180(+) feet. It maintains itself at almost perfect grade with respect to this elevation between Northfield Farms and Bellows Falls, a distance of 45 miles. Above the former locality planation is still proceeding with reference to the 180-foot baselevel, hence the conclusion seems warranted that Turners Falls mark the point to which headward gradation has extended from a lower baselevel and constitute what might be termed "cyclical falls."

This conclusion may at once be challenged with the contention that the existence of Turners Falls depends upon the superposition of the river across relatively resistant Triassic rocks; that upstream from the falls the lateral planation which is taking place at the higher level is proof of the efficacy of hard-rock barriers in causing terrace development in a single cycle; and that the features described are not proof of two distinct cycles, but of one.

These claims must ignore the fact that below the falls, where superposition was not a factor, the Connecticut is entrenched within degradational terraces that rise to the level at which planation is proceeding above the falls. Superposition, of course, explains why the river is not graded to a point still farther upstream—why, in short, the falls happen to be where they are at the given geological moment; but the significant fact is that degradation also took place with respect to the higher level downstream from the point where superposition occurred. The hard ridge is acting merely as a temporary stay in the progress of headward regradation.

Between Northfield Farms and Bellows Falls the gradient of the Connecticut is almost perfect, although it is by no means as flat as the profile of an older stream. It rises from 180 to 220 feet in the distance of 45 or 50 miles. In the southern part of this section the river is corrading laterally, but upstream it is still cutting vertically; and north of Brattleboro it is entrenched within two terraces, the lower at 280-320 feet, the higher about 420 feet. The lower is in large part aggradational, yet many degradational features must be referred to it. At Bellows Falls the stream is again superimposed across a resistant rock-barrier, upstream from which it is planing a narrow but conspicuous floodplain approximately at 300 feet. It maintains itself at grade with respect to this elevation beyond White River Junction, although as before it tends to become more markedly entrenched northward within the 420-foot terrace. Again the significant fact is the presence of flats or terraces at 300(±) feet both above and below Bellows Falls. In this case the cyclical origin of terraces, floodplain, and falls may be more readily conceded, because they lie at the level

of gradation during the post-glacial submergence of the Connecticut Valley. The narrow benches at 180 feet and 300 feet appear to be correlates respectively of the Wicomico and Sunderland terraces, which Barrell found clearly but weakly etched into the profile of the New England upland along the margin of Long Island Sound.[1]

In both of the cases described the erosional levels become more constricted upstream and finally pinch out against the stream channel. The river maintains itself at the same grade for some distance upstream from the point where they end and is youthfully entrenched within a higher terrace; finally the river, too, rises in a series of rapids and falls to the level of the next higher erosional surface. The pattern of the terraces is thus dendritic and, if plotted, would appear much like the rock pattern on an areal geologic map in a dissected region of horizontal sediments. The arrangement of the terraces and the mode of their development is traced through three cycles in the accompanying block diagrams (Figures 52, 53, 54), which are drawn to represent any typical case. The continuance of lateral planation on each level upstream from the point to which entrenchment has proceeded at the next younger level is perfectly illustrated by the Connecticut above Turners Falls and Bellows Falls. Equally convincing cases occur along all the large tributaries of the Connecticut at successsive terrace levels. It is in consequence of continued lateral corrasion, as the diagrams show, that each terrace maintains a constant width almost to its headward terminus. The expansion of terraces near the mouths of tributaries, a characteristic discussed on an earlier page, may also be visualized by reference to the diagrams. The theoretical nicety of adjustment between the features of each level cannot be expected in New England, however, because of the disturbing effects of glaciation.

The higher terraces along the Connecticut are as a rule more clearly defined and indicate cycles of erosion proportionately more protracted than the short post-glacial cycles which were responsible for the development of the Wicomico and Sunderland levels.

[1]The Sunderland level appears to be related genetically to the Pleistocene submergence of the Connecticut, Hudson, Champlain, and St. Lawrence valleys. Formation of the Wicomico terrace would, if the first assumption be true, mark a partly emergent stage post-dating maximum submergence and antedating the rise of New England to its present position above sealevel. It might, according to this interpretation, be a feature of early Recent time, although Barrell dates it as Pleistocene. If correlation of these erosional terraces is to be made with the more thoroughly studied events of glacial and post-glacial time, it is difficult to see how the comparatively horizontal gradients of the former can be reconciled with the steadily rising elevation of the features related to post-glacial submergence. Reconciliation seems possible only if it be postulated that central and northern New England was warped downward beneath the ice sheet and was re-elevated approximately to its pre-glacial position after the withdrawal of the ice and estuarine waters. The writers have had no opportunity to study the erosional terraces in relation to the features of Pleistocene submergence, and a problem of unknown magnitude appears to exist.

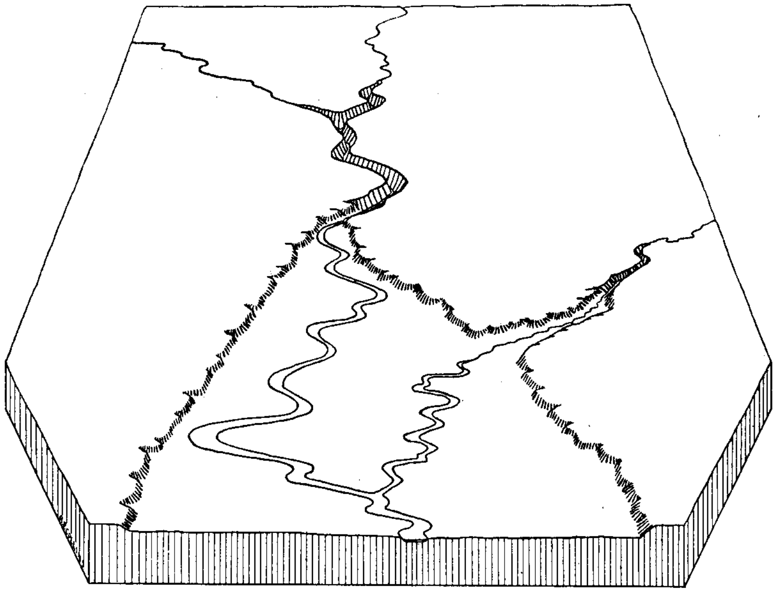

FIGURE 52.—Headward gradation of first-cycle gradational forms.

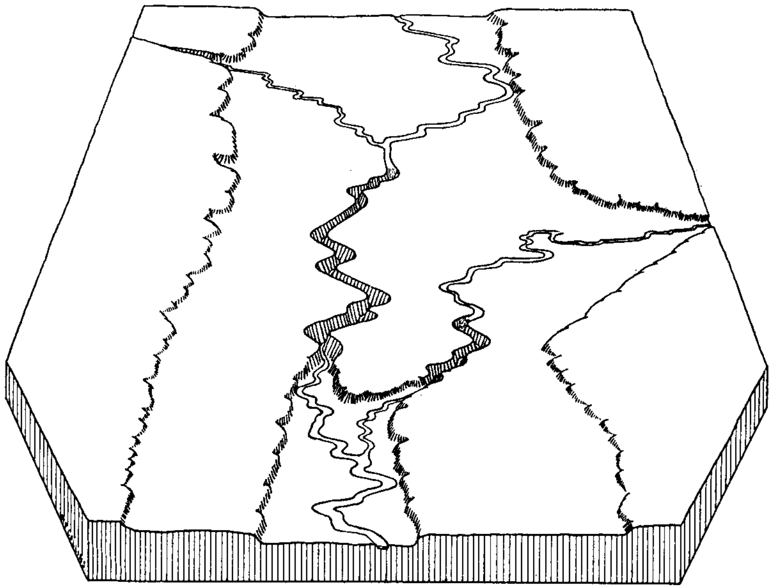

FIGURE 53.—Terrace development in the second cycle.

Casual study of the areal distribution of the higher levels suggests that some of the cycles were of far greater length than others. Yet, if an attempt be made to determine the relative importance and duration of each, the result is inconclusive, because each level varies in importance. As each is traced upon the upland and along the tributaries of the Connecticut, it is found to assume a place of major importance in some one section of each large stream system. Downstream, if preserved at all, it is represented by a few isolated monadnocks, upstream, if it was ever formed, it is found marginal to the river, or possibly it can be detected

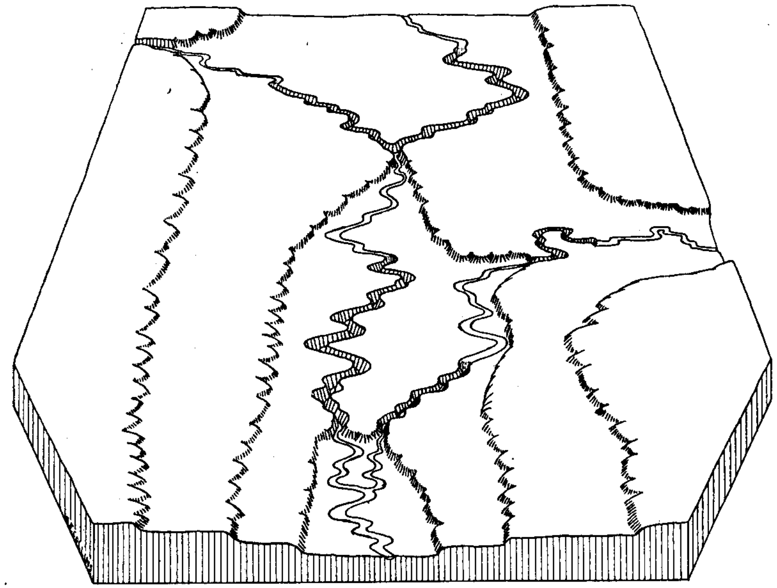

FIGURE 54.—Terrace development in the third cycle.

only in the valley slopes and in the gradient of the stream. This condition is a logical outcome of the principle that each erosional level is a progressing form which steadily advances headward along every river system in the region. Slowly it displaces an older level and is in turn displaced by a younger. Thus the terraces younger than the Litchfield (those below 1,200 feet) are relatively narrow and poorly developed along Connecticut River in Vermont, but each assumes a place of greater importance in Massachusetts and attains its greatest development in Connecticut. It seems probable that the cycles varied, perhaps considerably, in length; and some of the older ones appear to have been far longer than any of the more recent ones. It is not possible, however, to agree with Barrell's belief in a progressively shortened period for each successive cycle. His opinion was based on the dubious assumption that each erosional scarp still occupies the same position it had at the inauguration of the next cycle, and that the shortened radii of degradation from the scarps to the present coast are indices of relative duration. The writers attempted to estimate the proportionate lengths of some of the older levels, but, finding that the task required a familiarity with the erosional forms in southern New England, they were forced to abandon the attempt.

The failure of the terraces paralleling the Connecticut to rise an appreciable amount northward furnished an element of surprise in the present investigation. A northward inclination was to be expected because (1) features of post-glacial submergence, which rise about 2½ feet per mile northward, indicate arching that, presumably would affect the pre-glacial erosional terraces;[1] (2) Barrell, Davis, and others have stressed Miocene or pre-Miocene arching which, it is claimed, affected the entire central and northern Appalachian region, including New England; (3) Barrell's work ascribes moderate north and northwest slopes to each of the terraces south of Vermont, and it was to be presumed that their declivities would prove constant or slightly steeper northward. The discovery that the gradients of the terraces are measurable in inches per mile rather than in feet was a source of disturbance which led to fruitless efforts to prove that southern Vermont marks the crest of the Tertiary arch, north of which the landforms either maintain the same elevation or become lower. This possibility has not been wholly eliminated, but it has not been proved. It seems more probable from the data at hand that the slope of seven feet per mile which Barrell assigned to the higher terraces is too steep. It is based upon slopes which in most cases are projected from the southernmost monadnock which may be referred to a given terrace. These monadnocks have suffered an indeterminate amount of reduction and are wholly unreliable as a means of fixing the elevation of the seaward margins of the terraces. No attempt has been made by the authors, however, to verify this opinion or to correct the figures given by Barrell.

There is no way of explaining the fact that none of the terraces rises as rapidly as the features of post-glacial submergence, except by postulating depression of the upland surface under the weight of the ice and resumption of its original relative position after Pleistocene submergence. Such a postulate seems gratuitous, and is opposed by the fact that the gradient Barrell

[1] Fairchild, H. L., Post glacial marine waters in Vermont. Rpt. Vermont State Geologist, 1915-16, p. 4.

ascribes to the Sunderland and Wicomico terraces in Connecticut (two feet per mile) corresponds closely with the rise of the features of post-glacial submergence; but no alternate explanation can be proposed at the present time.

The essential horizontality of the erosional terraces of Vermont is a feature so at odds with current opinion that the authors were led to re-study their profiles and the barometric readings obtained in the field to determine any possible sources of error. None has been found, and their observations have been confirmed by Miss Pond, who finds the terraces of the Taconic section practically horizontal along the entire north-south belt which she studied. Apparently there, too, their position has no relation to the rise of 2½ feet per mile displayed by the estuarine deposits of the late Pleistocene.

A less direct line of evidence may also be utilized in refuting the claim that the erosional levels of New England are warped. In the Connecticut Valley the terraces rise sufficiently northward to satisfy the requirements of grade in a river that had developed to advanced maturity or old age. The widths of the terraces indicate that in each cycle the Connecticut attained this stage of development before the next cycle was begun, except during the Wicomico and Sunderland cycles, which have already been discussed. It is natural to find, therefore, that these lowest levels rise more rapidly than any of the older erosional surfaces. On the other hand, the flatness of the terraces in a north-south direction contrasts with their more evident, but still slight, rise in elevation westward along the tributaries of the Connecticut. This condition is normal, for the gradients of tributaries are generally steeper than those of the mainstream. It is barely possible that part of the rise westward may be the result of arching, but no evidence was found in support of this possibility. On the contrary, what data could be gathered on this question are adverse. As far as the present investigation has gone, therefore, it seems reasonable to conclude that the diastrophic history of New England has consisted wholly of vertical epeirogenic movements, unaccompanied by detectable amounts of permanent warping in any direction.

THE RELATION BETWEEN THE CONNECTICUT AND ITS TRIBUTARIES

A casual inspection of the topographic maps of southeastern and central Vermont suffices to show that each tributary within the Connecticut river system has one of two contrasted relations with the mainstream into which it flows. Practically all the tributary streams head in subsequent valleys, and many of them continue as subsequent streams from source to mouth. Although many of those which are wholly under structural control are small, there may be observed among them a tendency to increase in size westward, and their valleys increase in depth proportionately. The tendency is marked but is by no means universal. Many streams, on the other hand, maintain subsequent courses for variable distances below their heads and then abruptly turn at right angles to follow superimposed courses until they join the mainstream. Nearly all the tributaries of the Connecticut are superimposed for some distance above their mouths; and all of the larest, such as Deerfield, West, Saxtons, Black, Williams, Ottauquechee, and White rivers, are superimposed across the underlying structures for ten to twenty miles upstream from their confluence with the Connecticut. As a rule, though by no means an invariable one, the character of these major tributaries changes at or near the first line of monadnocks which fringes the western edge of the terraced upland. In the case of the small streams, however, the change occurs some place east of this line.

A study of the relations between the erosional terraces and any of the large tributaries mentioned above offers at once the explanation of their behavior. Superposition occurs at or near the western limits of some one of the higher terraces, more commonly the 1,900(±)-foot terrace, less commonly the 1,700(±)-foot or the 2,100-foot level. It is obvious that superposition occurs with reference to one of the old floodplains of the Connecticut. These streams were diverted from subsequent courses in one of the early erosion cycles in consequence of the development of the Connecticut's floodplain by lateral planation and aggradation. With uplift and degradation toward a lower base-level, they became entrenched across the underlying structures as they cut down through the alluvial veneer.

The smaller streams which rise upon the lower terraces have had a shorter history. They seem to have originated after the Connecticut had entrenched itself below the terrace, and after the alluvium of the floodplain was removed. All of them developed courses in response to the structure, and many of them join the older superimposed streams without changing their subsequent character. Some, on the other hand, effected a junction with the Connecticut at the lower level which it assumed; and wherever this occurred, the stream has maintained a superimposed course across all younger terraces, having followed the large river over alluvial materials as it abandoned one terrace after the other. Not uncommonly the smaller superimposed streams have been unable to grade themselves with reference to the later changes of level and so are strongly discordant with Connecticut River at the present time. In this connection post-glacial maladjustment

must be kept in mind as a factor which has in numerous instances produced comparable effects.

Of necessity, in each cycle every large tributary of the Connecticut formed a more limited floodplain of its own, as soon as its profile was perfected. It is to be expected, therefore, that its tributaries will also show analogous features of superposition with reference to it. This expectation is fully realized, especially in the cases of Deerfield and White rivers, and to a less conspicuous extent in the cases of other streams which drain the country west of the terraced upland. Their floodplains were narrower than the Connecticut's, hence the zone of tributary superposition is correspondingly narrow and, for the most part, is related to and restricted to the higher erosional levels.

The interrelation between tributaries, mainstreams, geologic structure, and erosional terraces is so ideal, notwithstanding local glacial modifications, that no more convincing proof of the fluvial origin and the cyclical character of the terraced upland can be asked. In cases where superposition has occurred, the streams indigenous to given terraces are superimposed across all the younger levels, unless they have been victims of stream piracy. It is possible to date the origin of groups of streams and to date the time of their diversion into the Connecticut across its floodplain accurately with respect to the cycles. As each group of streams associated with successively older and higher terraces has had a longer career, it is natural that in general their size, length, and depth of entrenchment should be roughly proportional to their age. For this reason the subsequent streams in the western part of the upland are usually larger than those situated nearer the Connecticut.

THE RELATION OF THE TERRACES TO TRIBUTARIES

Whereas each of the erosional terraces extends for a long distance upstream along the Connecticut before it pinches out, the width and extent of each are noticeably less along the tributaries, except near their confluence with the mainstream. Again the distribution of terraces may be compared with the rock pattern in an areal geologic map of a dissected plain or plateau. Along tributaries the valley walls are steeper, hence the width of the outcrop is less; the gradient likewise is steeper, and consequently each formation pinches out in a shorter distance than along the mainstream. Where tributaries and mainstream join, the flattened slopes make the outcrop broader. In the analogy employed, resistant, vertically jointed members will tend to outcrop in perpendicular cliffs, and the width of outcrop will, therefore, be approximately the same along mainstream and tributary, as well as at their junction. In the case of the erosional terraces the scarps between them tend to maintain the same angle of slope in every situation, and they may, therefore, be compared with the cliff-making members of the sedimentary rock-section.

The analogy seems to have few limits, for just as the cap-rock of a dissected low plateau may have higher members rising in mesas and buttes above it; and just as these higher members may become the cap-rock toward the more remote drainage divides, so with the erosional terraces. At a given locality one level dominates the upland adjacent to the streams, but outliers of the next higher level may rise above it as monadnocks; in areas more remote from the Connecticut the higher level assumes the place of dominance.

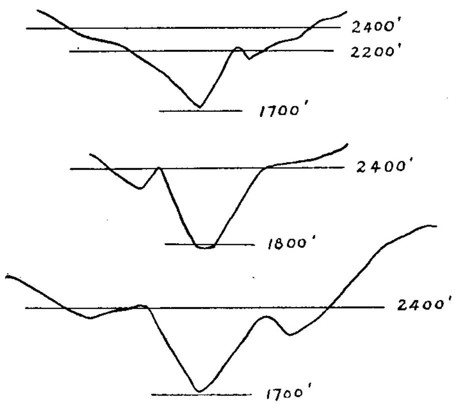

FIGURE 55.—Notched and terraced valley walls in the Deerfield River system.

In one respect the analogy must be qualified. In plains and plateaus stream and rock patterns are dendritic. In Vermont the stream pattern has been to a large degree molded by the regional north-south strike of the rocks; and as the terraces have developed in association with the streams, they tend in part to assume a trellis pattern. Differential rock-resistance has not played so large a part in Vermont, however, as it has in the central Appalachians. Except for the comparatively few resistant members which underlie the more prominent linear ranges of the Green Mountains, the rocks have proved somewhat homogeneous, and in the terraced upland fewer erosional features are dominated by the structure than might be expected. Monadnocks on its surface are generally aligned in accordance with the strike of the rocks; the young, poorly adjusted streams flow in strike valleys; but in a large number of cases the erosional scarps between levels appear to have merely a casual relation to the structure.

In the consequent valleys the widths of the terraces respond somewhat to the relative resistance of the rocks across which the streams have been superimposed. In water-gaps through hard layers it is common to find terraces restricted to widths of a few yards, or to find them respresented merely by changes in valley slopes, or, in numerous instances, to discover no trace of them at

all. Composite slopes of the type Barrell describes in Pennsylvania[1] are rare, but, on the other hand, notched or terraced slopes are numerous (Figure 55).

In the subsequent valleys the behavior of terraces is still more erratic. As the majority of these valleys have north-south trends, glaciation has been severe within them, and locally it has destroyed completely the narrower and lower benches. In Ottauquechee valley north of West Bridgewater, terraces and facets have been almost wholly obliterated, but few other valleys have been so strongly glaciated. On the other hand, where glaciation has not produced such destructive effects the development of the

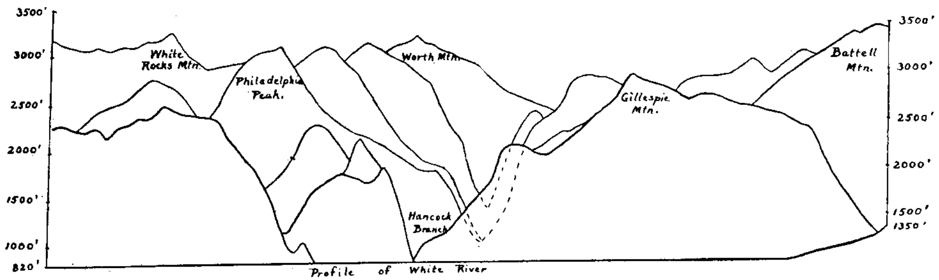

FIGURE 56.—Projected profile view from west from White River between Rochester and Granville showing accordance of peaks at the 3,200 foot (Dorset) level. Composite slopes suggest levels at 2,800 feet, 2,350 feet, 2,150 feet, 1,850 feet.

terraces has usually been rigidly restricted by the resistant outer walls of the valley. Older terraces may be missing or exceedingly fragmentary because they have been destroyed by lateral planation at a lower level, which, too, extended to the resistant stratum that bounds either side of the valley. Or, in consequence of the arrangement of monoclinal strata which exhibit varying degrees of resistance, terraces may be preserved on one valley wall only, as in sections of the White River valley near Rochester and Hancock (Figure 56).

The Wicomico and the Sunderland cycles have produced negligible to indeterminate effects on the tributaries of the Connecticut, but traces of practically all the older cycles have been preserved. The features of the New Canaan level at 420(+) feet show a greater degree of uniformity than those referable to most of the other levels. On Deerfield, Millers, West, and White rivers, and even on the Connecticut itself above White River Junction, waterfalls or rapids mark the lower limit of this level. Above the cyclical falls at Shelburne Falls, the Deerfield River valley is flat-floored, broad, and open; below them the river flows

[1] Barrell, Joseph, Rhythms and the measurements of geologic time, op. cit., p. 761 and following; The piedmont terraces of the Northern Appalachians, *op. cit.*, p. 347.

in an exceedingly young, gorge-like valley for several miles. The topographic features at the New Canaan level in the large valleys of Vermont and New Hampshire are nearly identical with those in the Deerfield valley of Massachusetts.

The higher terraces are often represented by upland "flats," within which the rivers are entrenched. These "flats" consist of gently sloping, graded surfaces, which in nearly all cases are graded toward the present positions of the rivers. Only rarely is there evidence that the streams have made local changes in their courses since the levels were developed. In such instances the evidence is to be found in the removal of a terrace on one side of

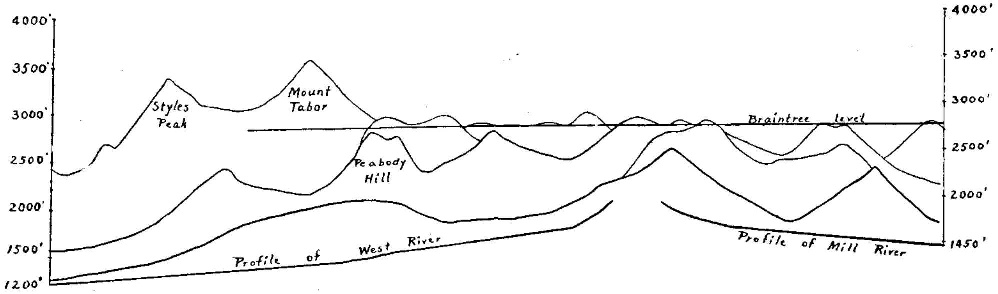

FIGURE 57.—Projected profile, view west-southwest from West and Mill rivers between Weston and Tarbelville showing development of Braintree 2,750 foot levels.

the valley, or in slight differences in the elevations and widths of the graded slopes on opposite sides of the valley. As was mentioned above, many of the tributaries which join the larger subsequent streams in the mountain belt west of the upland are superimposed for distances of one to five miles above their mouths. This feature is particularly prominent along the valley of White River, where superimposed tributaries are numerous. It is a common phenomenon also in the upper portions of Deerfield and West rivers (Figure 57). Along White River superposition seems to have been closely associated with the development of flood-plains at the 1,900-foot and higher levels, but some of the later cycles are represented by narrow benches which extend upstream along these small tributaries into the higher mountain belt (Figure 58).

One of the most striking features in south-central Vermont is the broad basinal depression drained by the headwaters of West River. In the field the writers referred to it as the Londonderry basin, giving the name from the town of Londonderry, which is situated in its east-central part. Here West River and its headwaters seem to have found a belt of comparatively nonresistant rocks, which they have carved into a broad topographic

lowland that is bounded on all sides by high, resistant monadnock ridges. Terrible, Markham, and Glebe Mountains hem it in on the east; Stratton Mountain and the high ridge south of Bondville shut it in on the south; Bromley Mountain and the associated ridge west of Peru enclose it upon the west; and a series of peaks and high divides separate it on the north from the comparatively low pass which the Rutland Railroad has utilized in crossing the state from Rutland to Bellows Falls. West River leaves the basin through a comparatively deep, young gorge situated at its southeastern corner. Within the basin it flows in a comparatively mature valley at an elevation approxmating 1,000

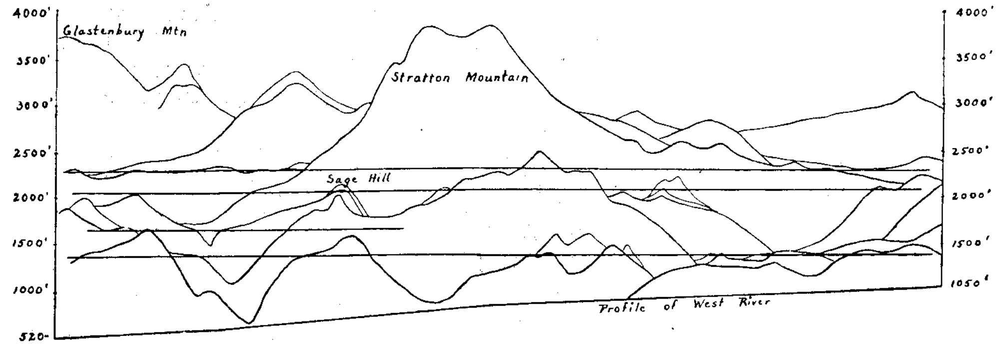

FIGURE 58.—Projected profile, view west-southwest from West River between Jamaica and South Londonderry, showing terrace at 2,300 feet (Becket), 2,050 feet (Canaan), 1,700 feet (Cornwall) and 1,380 feet (Goshen).

feet in the south, but rising rapidly northward in the vicinity of Londonderry to an elevation of 1,200 feet. Whereas its gradient is comparatively gentle at the two levels mentioned, it is relatively steep for a distance of 3½ to 4 miles where it drops from the higher to the lower. From the compound character of the gradient, as well as from the nature of the valley walls, it seems probable that both the Litchfield and Prospect cycles are represented.

The upland flanking the river appears strikingly composite when viewed from any eminence on the borders of the basin. Toward the south and southeast its dissected surface rises regularly to flat-topped or gently rounded hills which approximate 1,400-1,420 feet in elevation. A few glaciated knolls rise higher, some of them attaining heights above 1,600 feet. Toward the west and north, however, levels averaging 1,660-1,720 feet in altitude prevail, and a considerable portion of the basin consists of very flat surfaces at this higher level. The break between those levels approximating 1,400 feet and those at 1,700 is everywhere sharp and clear, a feature which leaves no doubt as to the composite character of the surface. Around the margins of the basin and upon the flanks of the high ridges which bound it dissected flats and spurs of greater or less extent occur at 1,900 feet, at 2,100 feet, and, less commonly, at 2,300-2,400 feet. So clear is the succession of levels in this region that it offered to the authors their first conviction of the cyclical character of the Vermont upland, and the region was made the subject of an intensive study. The character of the rocks seems to have been ideal for the development of each successive erosional surface, and here near the head of West River, where cycles penetrated but slowly, was an ideal place for the formation and preservation of each level. The older levels (Hawley at 1,900 feet, Canaan at 2,100(—) feet, and Becket at 2,300(+) feet), were crowded to the basin's borders, as the Cornwall and Goshen levels were extended, but they still exist in fragments large enough to make clear their cyclical origin (Figure 59).

Description of the erosional terraces associated with other streams and of the terraced upland in the inter-stream areas can add little to the details given above for selected, but typical sections along Deerfield and West rivers. Levels vary in importance from one place to another; locally they have succumbed to partial or complete destruction; in places they have never been formed. But in every portion of the region studied, upland, valley walls, and stream gradients are composite; their profiles flatten into graded slopes, or drop sharply in discordant slopes at elevations that are relatively invariable. Details differ within broad limits, and the record everywhere is imperfect; but the underlying plan is constant. Rather than add local descriptions that must inevitably be repetitious, the writers append a few profiles illustrative of terrace development at different levels in various portions of central and southeastern Vermont and northwestern Massachusetts (Figures 60 to 63). They have been selected because they show some one feature well, and for this reason a few of them represent ideal rather than typical conditions, whereas others emphasize certain imperfections that are not general.

The descriptive material presented both in the body of this paper and in the accompanying figures must indicate clearly how imperfect the cyclical record is. In any one section the presence of individual terraces can usually be called into question, and the writers must admit that, if their determinations depended upon the erosional forms of any single locality, their case for fourteen distinct cycles would be weak. Field study and the analysis of the 42 zonal profiles and of the many projected profiles employed in the present investigation show conclusively that every one of

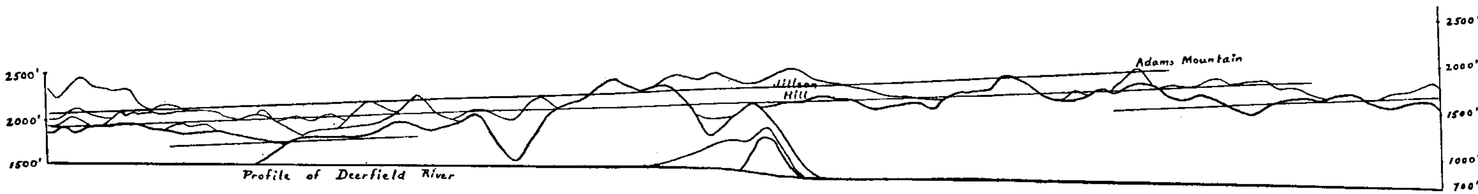

FIGURE 59.—Projected profile, view east from Deerfield River, showing terrace development at 2,100 feet (Canaan), 1,900 feet (Hawley), and 1,680 feet (Cornwall), between Hoosac Tunnel and Wilmington.

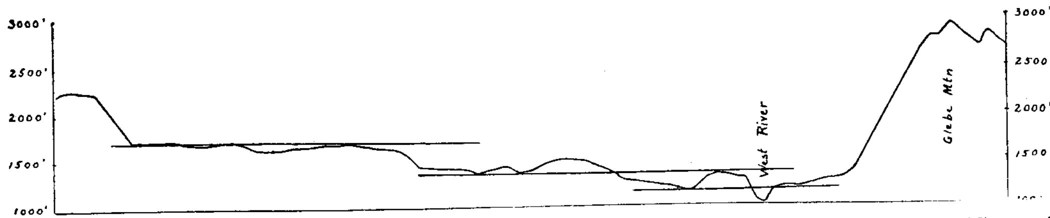

FIGURE 60.—Zonal profile across Londonderry basin, view north showing terraces at 1,660 feet (Cornwall), 1,360 feet (Goshen), and 1,200 feet (Litchfield).

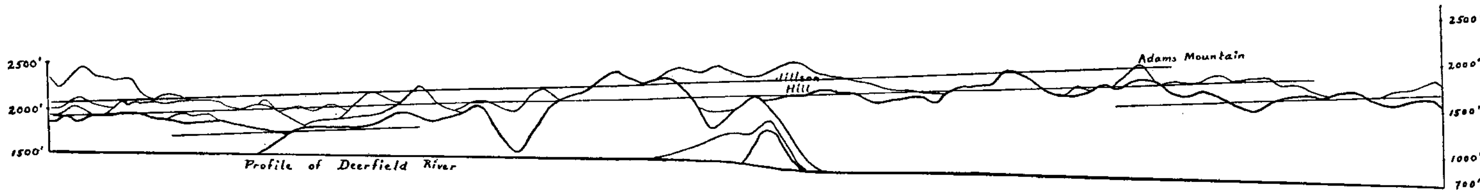

FIGURE 59.—Projected profile, view east from Deerfield River, showing terrace development at 2,100 feet (Canaan), 1,900 feet (Hawley), and 1,680 feet (Cornwall), between Hoosac Tunnel and Wilmington.

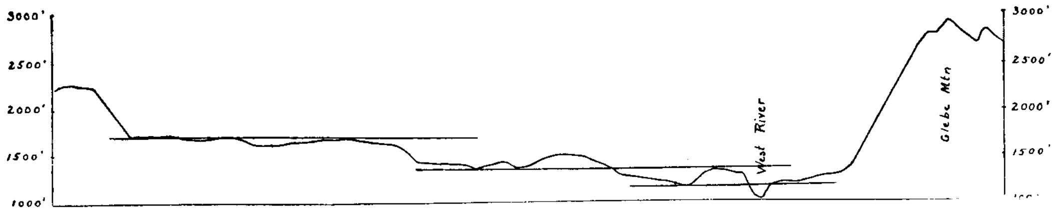

FIGURE 60.—Zonal profile across Londonderry basin, view north showing terraces at 1,660 feet (Cornwall), 1,360 feet (Goshen), and 1,200 feet (Litchfield).

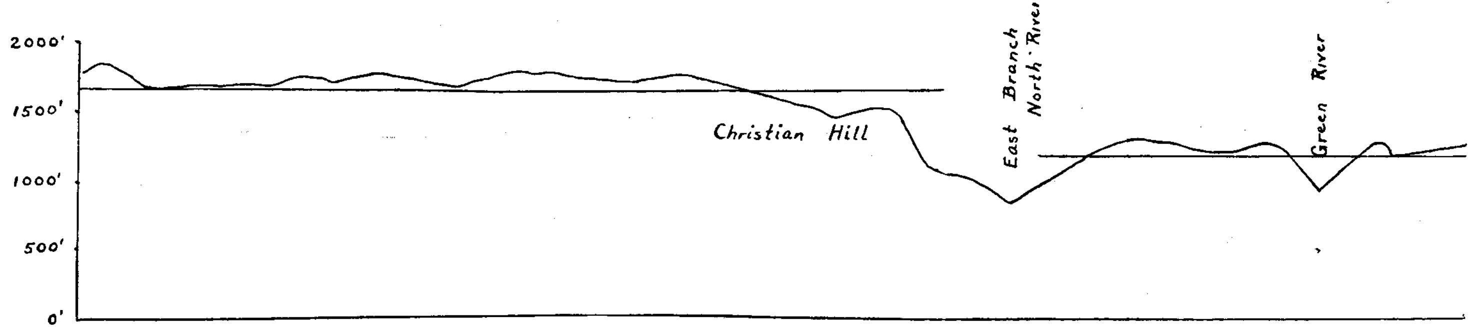

FIGURE 61a.

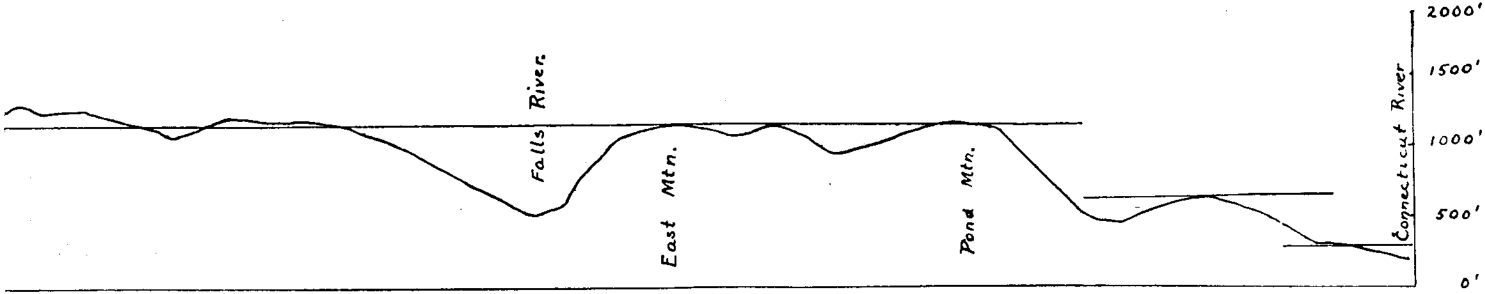

FIGURE 61b.

FIGURES 61a and 61b.—Zonal profile from Connecticut River at West Northfield to Christian Hill, showing exceptional development of levels at 1,680 feet (Cornwall), 1,190 feet (Litchfield).

the terraces which have been differentiated is a persistently recurrent feature in all portions of the district which has been minutely examined. Without a terrace theory the uplands west of the Connecticut and in the Green Mountains belt constitute a physiographic jumble, the development of which cannot be explained by the two or three cycles postulated by the adherents of the Davis theory. The acceptance of a cyclical theory, on the other hand, makes it possible to classify simply and clearly the many diverse elements which compose the surface of northern New England. Admittedly the theory has much to explain, and

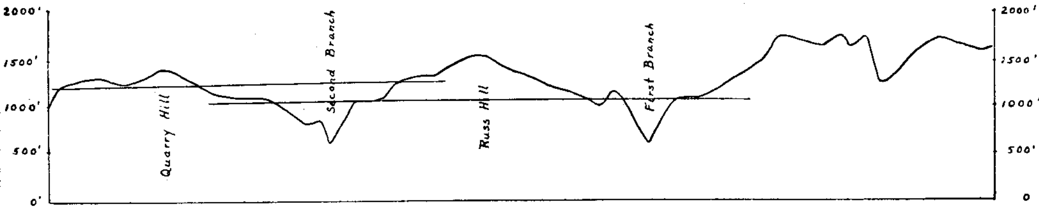

FIGURE 62.—Zonal profile across belt north of White River in Strafford and Randolph quadrangle, showing valley slopes terraced at 1,220 foot (Litchfield), and 1,040 foot (Prospect) levels.

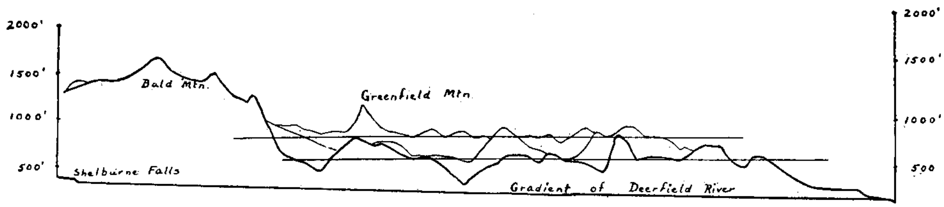

FIGURE 63.—Projected profile, view northeast from Deerfield River between Mill Village and Shelburne Falls, showing levels at 800 feet (Towantic), 560 feet (Appomatox).

explanation is seemingly an element of weakness. In Vermont the majority of explanations which are demanded concern themselves with the absence of a given terrace at some one locality where it might logically be expected. In every case which the authors have studied, the explanation has been readily provided by the local geology. On the other hand, the theory offers the only explanation for many of the physiographic forms, which appear to be related clearly and systematically to terrace development. Its strength rests on the many convincing topographic features which are found along Connecticut, White, Deerfield, and West rivers. For the terrace development which occurs along these streams the Davis hypothesis, however much modified, provides no explanation.

SUMMARY AND CONCLUSIONS

An analysis of the erosional landforms of the region lying between the Taconic section and Connecticut River and between Deerfield and White rivers, supplemented by studies in such widely scattered localities as northern Vermont, western and central Massachusetts, and southeastern New York, thus supports the conclusion reached by Barrell, that the New England upland is a terraced upland. Terraces may be formed by tectonic means, or by normal dissection in a single cycle if streams flow athwart resistant barriers, or if geologic structures offer favorable conditions for differential erosion. But none of these special explanations applies to New England. The moderate independence of structure which the terraces display, the sharp erosional scarps which usually separate them, the composite character of all stream profiles and of all broad upland areas, the extensive areas of flat or gently-graded surfaces at many, yet definite elevations, are features which *en masse* offer conclusive evidence that the erosional terraces were formed during numerous cycles of erosion, rather than during the two or three which many geologists still believe affected New England.

The cycles thus far identified number fourteen, exclusive of the present. Of these, eleven were differentiated by Barrell in western Connecticut and Massachusetts, and seven have also been recognized in the Taconic section by Pond. In all sections of western New England the terraces have been found at almost identical levels, and from this fact it must be concluded, notwithstanding the weight of earlier opinion and the disconcerting distribution of glacial and post-glacial features, that northern New England—perhaps all New England—has been raised in a series of vertical uplifts, in which warping or arching played no detectable part.

The erosional terraces in Vermont and northwestern Massachusetts are of fluvial origin. They are genetically related to the drainage systems, with which they are associated, in much the same way as horizontal sediments are to streams in a dissected plain; they have fluvial gradients; they are present in localities, such as the Londonderry basin, to which waves have never had access. From considerations of the similarity of the terraces in Connecticut to those of Massachusetts and Vermont, the fluvial form of the terrace pattern, the necessity of postulating fluvial dissection by any theory of origin, and the low gradients of the terrace profiles in every part of western New England, it seems probable that all must be considered the outcome of fluvial processes, and that marine abrasion aided not at all, or to a negligible extent. A review of some generally misinterpreted aspects of the fluvial cycle, as well as an analysis of the principles of marine abrasion, likewise proves the adequacy of the former to explain New England's landforms, and casts serious doubts upon the efficacy of the latter.

Thus the present investigation has aligned its authors with Barrell in the belief that New England's physiographic history can be explained only as the result of many erosion cycles. They cannot agree, however, that marine planation featured in that history, but are convinced that the entire development was dominantly, if not exclusively, fluvial. Final conclusions concerning the terraces in Connecticut must be reserved until they have been re-studied in field and laboratory, for a re-examination could not be undertaken in connection with the present investigation.

The results presented in this paper are incomplete, and its authors have been hesitant about publishing unfinished work. The only justification for publication is to be found in the conclusiveness of the evidence favoring the fluvial origin of the terraces in Vermont and Massachusetts, some of which were regarded as marine by Barrell, and in the unusual agreement among the results of three independent studies in three contiguous areas of New England. All of them are in complete accord, not only with regard to the presence of many erosional levels, but, more significantly, also with regard to the vertical positions which these levels occupy.

Completion of the work will involve (1) the correlation of the terraces in southern and central Vermont with those which have been differentiated along the Canadian boundary, by field work in the intervening country, much of which has not yet been mapped; (2) extension of the studies into Canada as far as the St. Lawrence lowland; into New Hampshire as far as the limits of the Connecticut River system; into western Vermont as far as the Champlain lowland; and into southeastern New York, where the relationship between the Reading Prong and the balance of the New England physiographic province may have important bearing upon the problem; (3) the preparation of a map showing the distribution of the terraces; (4) additional analytical study, both in the field and in laboratory, to differentiate more clearly between the Hawley and Canaan terraces, and between correlates of the Towantic and Prospect terraces.

In addition, the terraces in Connecticut need restudy to determine from their gradients and topographic form the applicability of the fluvio-marine hypothesis of Barrell. The possibility of warping or arching must also be more carefully considered, and the lower terraces must be studied in relation to the features of post-glacial submergence. Far more structural and lithologic information is necessary before any analysis of Vermont's erosional landforms can be considered definitive. And in addition to these broader problems, innumerable local ones invite investigation. The present article must, therefore, be regarded as a preliminary report, which is offered in the hope that it may help bring some order out of the chaos which the conflicting interpretations of Northern Appalachian physiography have created. The details presented will inevitably need refinement and revision as further studies develop facts which the authors missed; but some confidence is felt that the main thesis will survive the test of critical analysis.

ACKNOWLEDGMENTS

In the prosecution of this investigation help has been received from many sources: To Professor Douglas W. Johnson the authors owe their interest in the problem. The study could not have been completed without the generous assistance and encouragement which were given by President William Allan Neilson of Smith College, and Professor George H. Perkins. The home of Mr. and Mrs. E. J. Foyles in Rutland was, through their kindly hospitality, utilized as temporary headquarters in the course of field work. Miss Adela M. Pond has discussed with the authors the results of her work in the Taconic section, and has placed at their disposal preliminary and final drafts of her article, which have been used liberally for purposes of comparison. Mrs. Meyerhoff took as active part in the field work as the authors themselves and has helped in the preparation of the report. For all these aids the writers cannot be too grateful.

The writers wish also to thank Professor A. A. Heine, who has read their manuscript; and Miss Anne Burgess who assisted in its preparation. To Mr. Robert F. Collins they are especially indebted for the illuminating block diagrams, reproduced as Figures 9-11, which picture more clearly than their words the principles of cyclical terrace development.

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MINERAL RESOURCES, 1928

G. H. Perkins

Since the publication of the last Biennial Report there has not been very much change in the mineral production of Vermont.

As Vermonters well know, the "Mineral Products" of the State include no metals or at most a very small value, but consist almost entirely of the products of our quarries: granite, marble and slate. A small amount of limestone, a little soapstone, a by no means negligible amount of talc, about $100,000 worth of kaolin and other clay products, somewhat over $500,000 worth of lime—these materials seem to be all that Vermont has to supply to the markets of the country. Of these, as it is hardly necessary to notice, the building stones are far the most important. As heretofore Vermont produces a larger value of granite and marble than any other part of the United States, and also more than any other part of the world. At least this is true as far as statistics can be obtained. As for slate, Vermont has for several years been increasing its output and now, according to the Government reports, produces nearly 80 per cent. as much as Pennsylvania, which for many years has led in this stone.

In former Reports, the writer has explained with some fulness of detail the absence of coal or oil in the State and why the presence of such substances is impossible in a region of the geological character which is found in all parts of Vermont and it seems wholly needless to repeat what has been said, but every few weeks letters come to the Geologist asking for information as to the possibility of finding coal and especially oil in Vermont. At this time it must be sufficient to assert very positively that there is no possibility of finding any coal products in this State.

Probably some confusion is caused by the fact that years ago lignite was found in a very small and very peculiar formation in Brandon and during a scarcity of coal in 1903 some of this was mined and burned, locally.

Lignite is not coal, though it may take its place and in some of its forms it very nearly becomes coal, but the Brandon lignite, though it could be burned, was not coal nor did its occurrence indicate the presence of a bed of coal. The total amount of this lignite was not great and none has been obtained for more than twenty years, though diligent search has been made.

As far as there has been change in the production of building and monumental stone during the past two years it may be said

that, as for some years, the amount produced has been increasing both in quantity and value, though not so greatly as to be at all spectacular. I have found it impossible to so untangle various reports that precisely accurate figures could be given, but it may be confidently stated that, combining all varieties of rock products sold in Vermont during the past year, 1928, not less than $17,000,000 in value fairly represents the output.

GRANITE

Vermont for several years has led the world in the production and sale of granite. It is very difficult to calculate the exact amount of this stone which is annually produced in the State, as has been noted in former Reports, and as explained in the Report immediately preceding this.

It has been the custom of late years to give in each Biennial Report as complete a list of granite quarries and "cutting sheds" in the State as could be obtained, but because of amount of material given on the preceding pages this list is omitted in the present volume and the following list includes only those firms which operate quarries. Most of these also carry on finishing plants or what granite men call "cutting sheds." Of these latter there are in the State several hundred, many of them located in Barre and Montpelier. Others, a few in each place, are located in many towns.

The writer would be glad if his attention is called to any omissions in this list. It is desired that all quarries now worked be included, and any omission is unintentional. Some of the companies given in the list operate only a single quarry, others several, which may be adjoining or less commonly at some distance from each other.

Should any reader wish more complete information as to the occurrence and character of Vermont granite he is referred to former Reports and especially to the Report for 1926.

LIST OF GRANITE QUARRIES NOW OPERATED IN VERMONT[1]

Barre and Vicinity

It should be noted that none of the quarries are located in Barre City but are all in Barre Town a few miles from the City Hall.

Anderson Friberg Company.
Barclay Brothers.
Canton Brothers.
Jones Brothers Company.
Littlejohn, Odgers and Milne.
Marr and Gordon.
Pirie Estate.
Rock of Ages Corporation.
Smith, E. L. and Company.
Sanguinetti Brothers.
Straiton, George.
Vermont Quarry Company.
Wells and Lamson.
Wetmore and Morse.

[1] In preparing this list the Geologist wishes to acknowledge the very kind assistance of Mr. P. I. Bailey, Secretary of the Granite Manufacturers Association of Barre, Mr. B. J. Hall of Hardwick and others.

Barton

Barton Granite Company.
Crystal Lake Granite Company.

Beebe Plain

Standard Quarries Company.

Bethel

Woodbury Granite Company.

Chelsea

Brocklebank Granite Company.

Groton

Barre Quarry Company.
Groton Quarry Company.

Hardwick and Woodbury

Ambrosini and Company.
Couhig, M. J.
Fletcher, E. R.
Robie, L. J.
Thomas and Company.
Vermont Quarries Company.
Woodbury Granite Company.

Kirby

Burke Granite Company.
Kirby Granite Company.

Newport

Le Casse, S. J.

North Derby

Wilkinson, Frank.

South Ryegate

Gibson, C. E.

Williamstown

Jones Brothers Co.
Williamstown Granite Co.

MARBLE

While there are a large number of companies dealing in granite and slate, the marble deposits are worked by a few companies. Those now operating are as follows, as Mr. N. C. Peterson of the Vermont Marble Company informs the writer.

Colonial Marble Company. Main Office, Rutland. Manufacturing Plant, Rutland. Quarries, West Rutland.
Green Mountain Marble Corporation. Office, Clarendon. Manufacturing Plants and Quarries, Clarendon, Dorset, West Rutland.
Venetian Marble Company. Office, Rutland. Quarries, Pittsford.
Vermont Marble Company. Main Office, Proctor. Manufacturing Plants, Proctor, West Rutland, Rutland, Center Rutland, Manchester, Pittsford, Middlebury, Swanton. Quarries, Proctor, West Rutland, Danby, Dorset, Pittsford, Brandon, Isle La Motte, Swanton, Roxbury, Rochester.

SLATE

There has been of late increased activity in the slate business, new and more efficient machinery has been introduced in the mills, new processes in the preparation of slate for various uses. Serial No. 2766, Bureau of Mines, August, 1926, gives detailed accounts of some of these.

A list of active slate companies in this State is as follows:

Castleton

P. F. Hinchey and Company, Hydeville. Mill stock only. Green, purple, mottled.
Penrhyn Slate Company. Mill stock only. Mills at Hydeville. Lake Bomoseen, Scotch Hill. Green, purple, mottled.

Hydeville Slate Works. Mill stock only. Green, purple, mottled.
John Jones Slate Company, Castleton. Mill stock only. Green, purple mottled.
Lake Shore Slate Company, West Castleton. Mill stock only. Purple, mottled.
Stoss Milling Company, Poultney. Ground slate only.

Fair Haven

C. M. Beach Slate Company. Purple.
Clark and Flannigan Slate Company. Mill stock, roofing, unfading green, purple, gray, mottled.
Durick, Keenan and Company. Mill stock only. Mottled, purple.
Eureka Slate Company. Roofing slate. Unfading green, purple, mottled.
Fair Haven Marble and Marbleized Slate Company. Purple, green, mottled.
Locke Slate Products Corporation. Mottled green and mottled purple.
McNamarra Brothers Slate Company. Electrical slate only.
Mahar Brothers Slate Company. Mill stock and roofing slate.
Old English Slate Company. Roofing slate. Purple, mottled. Office, Boston, Mass.
W. H. Pelkey Slate Company. Roofing, green.
Vermont Milling and Products Corporation. Ground slate only for roofing. Mill at Poultney. Office, Fair Haven.
A. R. Young Slate Company. Mill stock only.

Poultney

Auld and Conger Company. Roofing. Unfading green, weathering green, sea green, purple, mottled.
Cambrian Slate Company. Roofing. Purple, sea green. Office, Granville, N. Y.
Donnelly and Pincus Slate Company. Roofing. Unfading green, purple, mottled.
General Slate Company. Roofing. Sea green, mottled, purple, gray.
New York Consolidated Slate Company. Roofing. Green. Unfading green, mottled.
F. C. Sheldon Slate Company. Roofing. Purple, sea green.
Staso Milling Company. Ground slate only.
United Slate Company. Roofing. Mottled.
Vendor Slate Company. Roofing. Sea green, mottled, purple, gray, unfading green.

West Pawlet

Rising and Nelson Slate Company. Roofing. Sea green.

Wells

O'Brien Slate Company. Roofing. Purple, sea green.
Burdette and Hyatt. Quarries in Wells. Office, Whitehall, N. Y.
Norton Brothers Slate Company. Quarries in Vermont and New York. Roofing. Green, purple, red.
Progressive Slate Company. Quarries, Vermont and New York. Office, Granville, N. Y. Purple, green, red.
O. W. Owens and Sons Slate Company. Quarries, Vermont and New York. Office, Granville, N. Y. Green, red, purple. Roofing.
F. C. Sheldon Slate Company. Quarries in Vermont. Office, Granville, N. Y. Roofing. Sea green.
O. W. Thomas. Roofing. Sea green.

Vermont Slate Company. Quarries in Vermont. Office, Granville, N. Y. Roofing. Sea green, purple, red.
Williams (H. G.) Slate Company. Quarries in Vermont and New York. Office, Granville. Purple, red, green.

TALC AND SOAPSTONE

The list of these companies is as follows:

American Mineral Company, Johnson.
Magnesia Talc Company, Waterbury.
Eastern Talc Company. Mines at East Granville, Rochester. Main Office, Boston, Mass.
Vermont Talc Company, Chester Depot.
American Soapstone Finish Company, Chester Depot.

LIME

The list of these companies is as follows:

Amsden Gray Lime Company, Amsden.
Missisquoi Lime Company, Highgate Springs.
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, West Rutland.
Pownal Lime Company, Pownal. Office, 92 State Street, Boston, Mass.

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