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OF THE

STATE GEOLOGIST

ON THE

MINERAL INDUSTRIES AND GEOLOGY

OF

VERMONT

1923-1924

FOURTEENTH OF THIS SERIES

GEORGE H. PERKINS

State Geologist and Professor of Geology
University of Vermont

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THE GEOLOGY OF SHOREHAM, BRIDPORT AND FORT CASSIN, VERMONT.

EDWARD J. FOYLES

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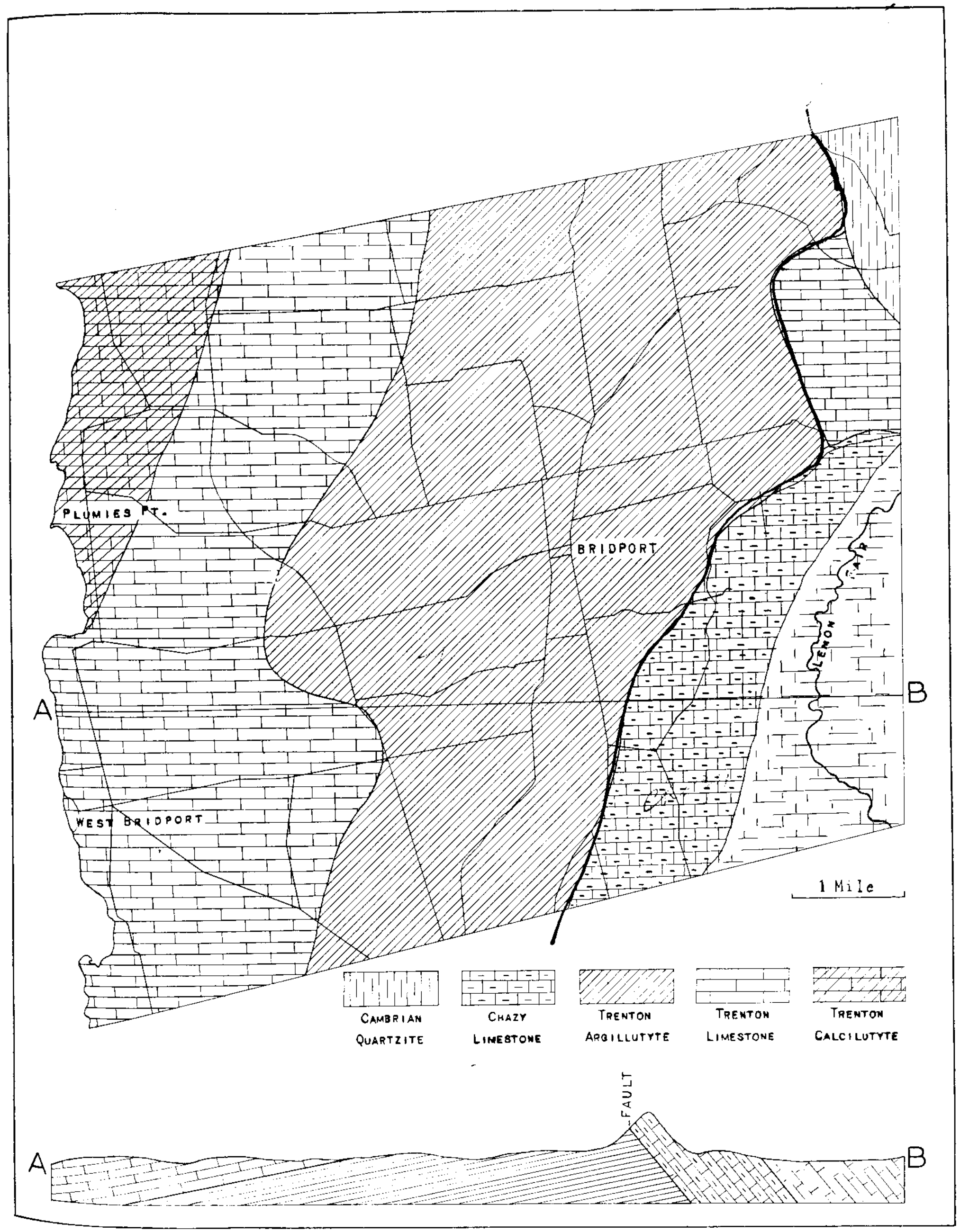
INTRODUCTION.

The present paper is the second of a series in which I am attempting to show the true ages of those rocks in the Champlain valley of Vermont which have been called Beekmantown [1, pp. 1-25][1]. Part of the area studied is pictured on the maps (Plates XV and XVI), which include the towns of Shoreham and Bridport in western Vermont. The reader is referred to the Ticonderoga, Brandon and Port Henry topographic maps published by the United States Geological Survey for a more detailed study of the localities listed in this paper. The district may be reached by automobile from the railroad at Middlebury, Vermont. Sections were made and fossils collected within the one hundred square miles of the area.

In the summer of 1921 three weeks were spent in field work, and in the summer of 1922 another three weeks were given to checking the previous work and adding to the data already acquired. The results of this work were published in the Thirteenth Report of the State Geologist of Vermont [2, pp. 71-86]. In the summer of 1924 three weeks were spent in the field. The field work has been supplemented by laboratory studies of the fossils from Shoreham and Bridport, and more particularly the

[1] The numbers within brackets refer to the bibliography attached to this paper.

PLATE XV.



Geological map of Bridport.

fauna of Fort Cassin at the mouth of Otter Creek, where an attempt had been made to show that the rocks are not Beekmantown in age, but belong to higher horizons.

I wish to acknowledge my indebtedness to Drs. Chester A. Reeds and the late Edmund O. Hovey of the American Museum of Natural History for their assistance in providing part of the time for field work. I also wish to thank the State Geologist for his help in furthering this study.

SHOREHAM AND BRIDPORT.

PHYSIOGRAPHY.

This area possesses the nature of a glaciated rolling plain which is known as the Champlain lowland. Aside from ground moraine, glaciation is evidenced by numerous undrained areas and marshes, by occasional waterfalls, and by a lack of systematic relation between the higher lands and the stream courses. It is probable that glaciation effaced many topographic features, perhaps filling and obliterating many small valleys and smoothing down many hills. Glaciation interrupted the cycle of erosion that was in progress before the ice period, and since the glacier withdrew, erosion has been renewed. A distinct north-south trend of the elevations is caused partly by the direction of the ice movement and partly by the attitude of the underlying rocks.

The topography and drainage are youthful, a youth that was superimposed upon surfaces that were in various stages of their erosion history before the ice affected them. Only one cycle of erosion is apparent, that being the post-Tertiary trenching of the streams in the New England plateau. The area represents only surface drainage.

STRUCTURAL GEOLOGY.

During the Cambrian and Ordovician periods the valley between the Green Mountains and the Adirondacks was partly filled with sediments which became consolidated by induration and pressure. At some unknown time after the cessation of deposition the Green Mountains were disturbed and moved westward. This movement caused the sediments in the valley to bow upward, forming a low dip to the west and a sharper dip to the east. As the westward movement continued the anticline broke along its axis and the east rocks rode up onto the west limb of the anticline. Continued westward movement of the Green Mountains pushed the east limb of the anticline farther onto the west limb. The rocks of the west limb were not greatly disturbed thereafter, but those of the east limb were forced on end, bent into drag folds and variously faulted. This movement ceased at some unknown time and the processes of erosion smoothed the

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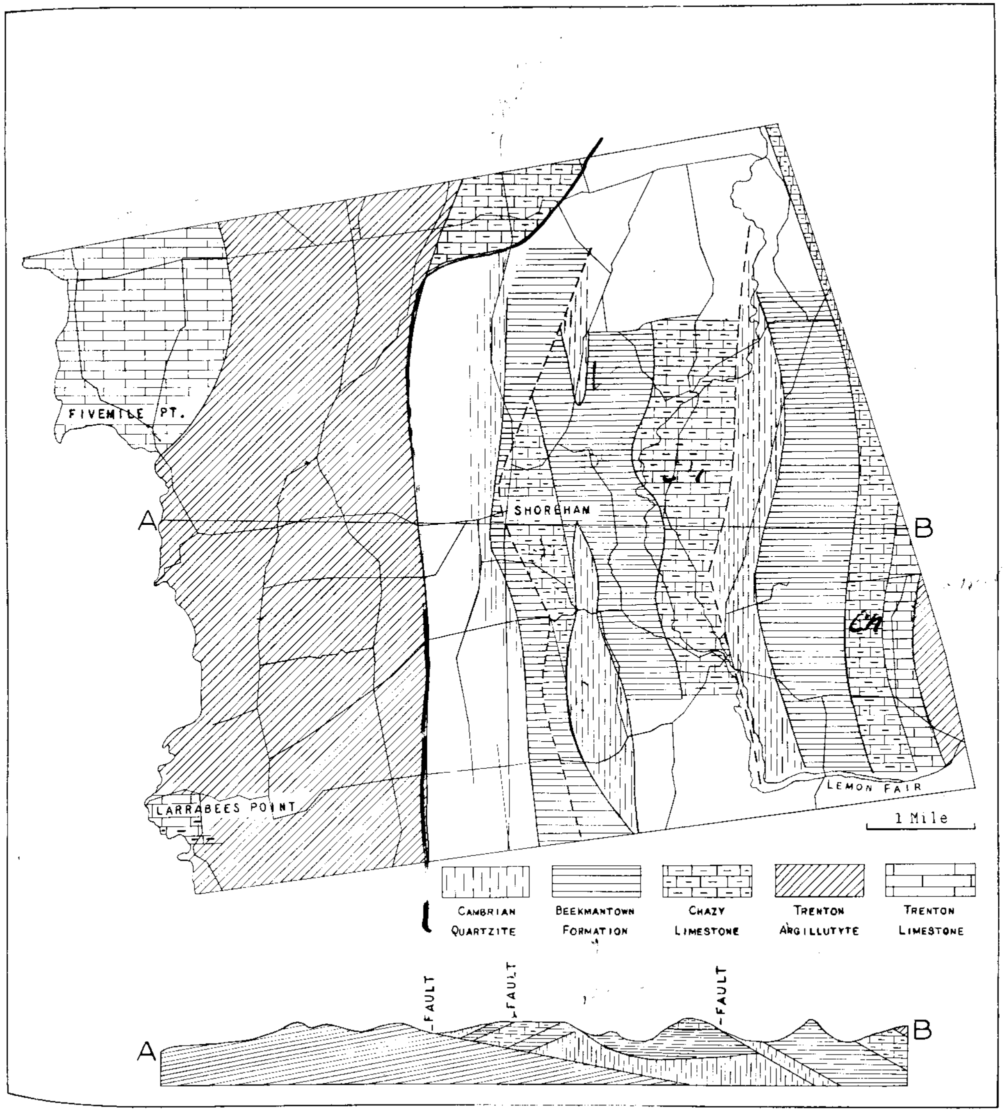
broken landscape. The observer now sees the gently sloping and little disturbed west limb of the anticline projecting from beneath the tilted fragments of the east limb. This in general was the course of events in this area after the close of the Ordovician.

The following illustrations (Plates XV and XVI) may serve to indicate the structural conditions which now obtain in Shoreham and Bridport. The rocks in southern Shoreham dip east and west on an anticline or drag fold at angles varying from 30° along the axis to 80° at places one-half mile to the east. The strike of the strata is generally N. 18° W. The field evidence indicates that the rocks have been subjected to great pressure from the east. In the great westward movement of the strata as a whole, many sections were dislocated and dragged behind. On the Whiting-Shoreham road sheared rock exposures and revoluted sections of strata indicate a long fault running east-west. One-half mile south of Shoreham Center a large section of strata has dragged behind in the westward movement of the rocks and is bounded on either side by transverse normal faults. These rocks lie upon Trenton beds which slope gently to the west.

An interesting exposure of the Beekmantown may be seen in the Bascom Ledge, which is situated two hundred feet south of the Laura Bascom farm at East Shoreham, Vermont. It consists of a high, steeply sloping bank facing the west. The strata dip 15° to the east and the strike is north-south. The rocks exposed consist of division D-3 and D-4 of the Beekmantown as defined by Brainerd and Seely or the Chazy of the writer. At the top of the bank the thin, tough shaly layers are plainly evident in division D-4. The intraformational conglomerate is disposed in patches throughout the rock. In one place I saw the coils of a gastropod one inch in diameter outlined in the conglomerate. The rock is distorted in some places. Half way down the slope the one-inch ridges of division D-3 are seen. At least two horizons in this stratum are very fossiliferous, but evidence of early life may be found in nearly all levels of the deposit. Twenty-five feet below the contact of the two beds the outlines of several coiled gastropods are etched upon the surface of the rock. One hundred feet below the contact the Chazy fossil, *Isotelus platymarginatus* Raymond, was found in abundance.

In Bridport the structure is not so complicated as it is in Shoreham. In the southern part of the town, along the Lemon Fair, the rocks have been bent into anticlines and synclines. The valley through which the Lemon Fair flows in going from Shoreham into Bridport is caused by a fault. Along the sides of this valley the strata have been greatly twisted and broken up. This fault may continue northeastward along the western margin of the river valley. At least one sheared outcrop of Chazy rock

PLATE XVI.



Geological map of Shoreham.

on the east side of Hemingway Hill tends to support this theory. In the east central part of the town the Chazy strata have been shoved up on end over the Trenton. The Cambrian quartzite of Grand View Mountain projects onto the Trenton in northeastern Bridport. In a traverse east from the southern end of Bridport village shale was encountered as far east as the east side of the road on the west side of the 500′ hill. The original bedding planes can be seen in the shale with the obscure cleavage planes of slate crossing them at an angle of 45°. Concretions were found in the shale, which in some places was crossed by thin layers of lime. Two beds of limestone were found on the hill. The west bed weathered gray, and the east bed weathered drab and was crossed with fine ridges of silica. The strike of the beds was N. 20° E. and the dip was 50° easterly. No fossils were found.

An anticline of shale was observed one-half mile east of Bridport on the road leading to Middlebury. The shale was composed of alternating bands of thick (1″) and thin (¼″) layers which were crossed by the cleavage planes of slate.

In a section which crossed Hemingway Hill to the Lemon Fair River drab, brown and gray strata of the Chazy were seen dipping steeply to the east to the edge of the river flats.

STRATIGRAPHIC GEOLOGY.

Owing to the presence of ground moraine and the Champlain clays this area does not possess many favorable outcrops for a successful study of its stratigraphy. The Cambrian and Ordovician periods are represented.

CAMBRIAN.

The Cambrian is a white, yellow and brown quartzite in Shoreham, and in northeastern Bridport it also contains red layers. It is very resistant and causes some of the highest elevations. In southern Shoreham the Cambrian forms the center of an anticline and is flanked on either side by the Ordovician. No evidence has been discovered to prove that the Ordovician lies disconformably upon the Cambrian, and it is quite possible that the Ordovician extends below this generally accepted level.

ORDOVICIAN.

LITTLE FALLS.

The first stratum of the Ordovician may be correlated with the Little Falls. Megascopically it is a dark, iron-gray magnesian limestone, more or less siliceous. Microscopically it is coarse-textured. Crystal outlines of the primitive rhombohedron denote dolomite which may be distinguished from the calcite matrix which has marked cleavage traces and lamellar twinning. The dolomite crystals show a yellowish-brown tint. Small cavities and crevices formed by shrinkage during dolomitization are filled with silica. Zones of growth may readily be seen in the dolomite crystals.

TRIBES HILL.

The second stratum may be correlated in part with the Tribes Hill. Megascopically it is a dove colored limestone mingled with light gray dolomite. Microscopically it is medium textured, and in a matrix of calcite there are sub-circular, finer-textured dark areas of dolomite.

BEEKMANTOWN.

The third stratum is Beekmantown and corresponds to Stage C, section 1 of Brainerd and Seely. Megascopically it is a gray, thin-bedded, fine-grained calciferous sandstone. Microscopically it is composed of fine-grained, sub-angular crystals of sand with an interstitial calcareous cement.

Stage C, section 2, is composed of a magnesian limestone in thick beds. Microscopically it is coarse grained with calcite crystals in various stages of dolomitization.

Stage C, section 3, is a light gray sandstone. Microscopically it is finely crystalline and is composed of sub-angular grains of beach sand.

Stage C, section 4, is a magnesian limestone containing chert. Microscopically it is finely crystalline. Small cavities and crevices formed by shrinkage during dolomitization are filled with silica.

Stage D, section 1, is a blue limestone. Microscopically it is medium grained and the crystals exhibit evidence of cleavage. Cloudy crystal outlines indicate the early stages of dolomite crystals.

Stage D, section 2, is a drab and brown magnesian limestone. Microscopically it is medium grained and is composed of calcite crystals in various stages of dolomitization.

CHAZY.

Stage D, section 3, belongs to the Chazy. It is a sandy limestone. Microscopically it is medium grained and exhibits calcite crystals interspersed with patches of silica.

Stage D, section 4, is composed of blue limestone beds separated from each other by thin layers of shale. The limestone is sometimes conglomeratic. Microscopically it is medium grained and shows dolomite crystals in a matrix of calcite crystals throughout which are scattered grains of silica. Wide bands of silica traverse the slice, which is also impregnated with bands of ferruginous material.

Stage E is a fine-grained magnesian limestone weathering drab, yellow or brown. Microscopically it is fine to medium grained. In a matrix of calcite crystals there are scattered dolomite crystals in various stages of development.

TRENTON.

The Trenton formation is composed of dark gray shales, limestones and shaly limestones.

PALAEONTOLOGY.

The oldest rocks of Shoreham and Bridport are sparsely fossiliferous. No fossils were found in the Cambrian. The Beekmantown has yielded a few forms, the most striking being the Cryptozoon. It is in the Chazy that we find more abundant evidence of former life, the gastropods and trilobites being the most prolific forms. The Trenton beds enjoy the distinction of being the most fossiliferous rocks in the area. In these strata one may find an abundance of bryozoa, brachiopods, cephalopods and trilobites. This in general is the palaeontologic aspect of the rocks in Shoreham and Bridport.

The following lists of fossils have been collected in the two townships and are assigned to the horizons of the Ordovician as indicated in part by the author [2, p. 4].

BEEKMANTOWN.

TRIBES HILL.

Cryptozoon steeli Seely.
Cryptozoon wingi Seely.
Holopea sp.
Orthoceras primigenium Vanuxem.

STAGE C, SECTION 1.

Scolithus minutus Brainerd and Seely.

STAGE D, SECTION 1.

Maclurites affinis (Billings).
Ophileta complanata Vanuxem.
Leperditia nana (Jones).

CHAZY.

Bathyurus extans Hall.
Bucania tripla Whitfield.
Eccyliomphalus lituiformis (Whitfield).

Isotelus platymarginatus Raymond, Stage D-3, Bascom Ledge, Shoreham.
Isochilina seelyi (Whitfield).

TRENTON.

The most favorable place to study the Trenton is at the ferry landing at West Bridport. Here a cliff twenty feet in height contains many layers which are filled with fossils. Specimens were collected at various levels on the face of the cliff and are listed below.

Water level, July 24, 1924.
Prasopora simulatrix Ulrich.
Plectambonites sericeus (Sowerby).

2 ft. level.
Orthis tricenaria Conrad.
Plectambonites sericeus (Sowerby).
Cryptolithus tessallatus Green.

3 ft. level.
Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman).
Orthis tricenaria Conrad.
Plectambonites sericeus (Sowerby).
Trematis terminalis (Emmons).
Calymene senaria Conrad.
Cryptolithus tessallatus Green.

4 ft. level.
Prasopora simulatrix Ulrich.
Palaeoglossa trentonensis (Conrad).
Platystrophia biforata (Schlotheim).
Plectambonites sericeus (Sowerby).
Trematis terminalis (Emmons).
Cryptolithus tessallatus Green.

5 ft. level.
Platystrophia biforata (Schlotheim).
Plectambonites sericeus (Sowerby).
Cryptolithus tessallatus Green.

6 ft. level.
Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman).
Palaeoglossa trentonensis (Conrad).
Platystrophia biforata (Schlotheim).
Plectambonites sericeus (Sowerby).
Zygospira recurvirostris (Hall).
Calymene senaria Conrad.
Cryptolithus tessallatus Green.

7 ft. level.
Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).
Cryptolithus tessallatus Green.

9 ft. level.
Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).

12 ft. level.
Plectambonites sericeus (Sowerby).

13 ft. level.
Platystrophia biforata (Schlotheim).
Plectambonites sericeus (Sowerby).

14 ft. level.
Plectambonites sericeus (Sowerby).
Zygospira recurvirostris (Hall).

15 ft. level.
Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).

16 ft. level.
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).

17 ft. level.
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).
Isotelus gigas deKay.
Cryptolithus tessallatus Green.
Endoceras proteiforme Hall.

18 ft. level.
Prasopora simulatrix Ulrich.
Cryptolithus tessallatus Green.

19 ft. level.
Plectambonites sericeus (Sowerby).

20 ft. level.
Dalmanella testudinaria (Dalman).
Platystrophia biforata (Schlotheim).
Plectambonites sericeus (Sowerby).
Isotelus gigas deKay.

On the Bridport-Middlebury road, two miles from Bridport, an anticline of Trenton limestone is exposed. The rocks at this locality yielded *Prasopora simulatrix* Ulrich, *Dalmanella testudinaria* (Dalman) and *Cryptolithus tessallatus* Green.

Another locality of note is in the northwest corner of the town of Bridport where the Trenton rocks forced up by frost action have been picked up in the fields and utilized in making stone walls. The following list of fossils was collected from these walls.

Prasopora simulatrix Ulrich.
Dalmanella testudinaria (Dalman)
Schizocrania filosa Hall.
Plectambonites sericeus (Sowerby).
Zygospira recurvirostris (Hall).
Conularia trentonensis Hall.
Sinuites cancellatus (Hall).
Calymene senaria Conrad.
Cryptolithus tessallatus Green.
Othoceras amplicameratum Hall.
Orthoceras tenuitextum (Hall).

In the northwestern part of Bridport the limestone is succeeded by a shaly limestone which is typically exposed on the Herman Smith farm where *Glyptograptus amplexicaulis* (Hall) was found.

THE GEOLOGY OF FORT CASSIN.

INTRODUCTION.

The geology of Fort Cassin is included in this paper because it has a definite bearing upon the geology of the townships of Shoreham and Bridport. A map of the geology of the region about Fort Cassin [3, p. 297] shows that the rock forming the peninsula is an isolated section of strata connected to the mainland by alluvium deposited at the mouth of Otter Creek. Brainerd and Seely [1, p. 20] correlated the beds at Fort Cassin with the upper part of stage D of their Beekmantown in Shoreham. I have accumulated evidence to show that the Fort Cassin beds have been in part erroneously correlated with this horizon [2, pp. 79-83]. By studies of the Fort Cassin type and figured specimens in The American Museum of Natural History and fossils collected in the field it is hoped to demonstrate the true ages of the Fort Cassin strata.

Beginning at the top, the succession of beds at Fort Cassin is as follows:

BLACK RIVER.

Dolomite weathered yellow .... 3′+
Black siliceous limestone .... 6′

DISCONFORMITY.

CHAZY.

Thin, shaly limestone merging into massive beds at the top. .34′
Impure limestone with steel-gray appearance on fresh fracture, but weathering to a rusty color .... 6′
Sandy limestone weathering in parallel ridges one inch apart. Dip 5° south on the northwest point ....10′+

Considering its interest in geological history a short account of the recent history of Fort Cassin may not be amiss in this Report. In the course of the War of 1812-14 a small breastwork was thrown up on the north side of the mouth of Otter Creek where Lieutenant Cassin of the navy and Captain Thornton of the artillery with 200 men repulsed a large British force sent out from Canada to destroy the American fleet fitting out at Vergennes. Macdonough was at this time at Vergennes, and as soon as he was informed that the British flotilla had entered the lake, he ordered Lieutenant Cassin with a small group of sailors to reinforce Captain Thornton who had been sent from Burlington with a detachment of light artillery to man a battery which had been erected at the mouth of Otter Creek, or as called by the French, *La Riviere aux Loutres*. A brigade of Vermont militia was also ordered out and was advantageously posted to oppose the enemy in case he should attempt to land. At daybreak on the morning of May 14, 1814, eight of the British galleys and a bomb sloop anchored off the mouth of Otter Creek and commenced a warm fire upon the battery, which was promptly returned. A brisk cannonade was kept up by both parties for one hour and a half when the attack was abandoned. [6, pp. 198-199, 207].

The original breastwork was composed of slabs of rock collected along the shore and was covered with earth dug out from behind this enforcement. All that now remains of the original fortification is a low ridge of earth on the southwest point of the Fort Cassin promontory.

It was not until 1886 that further notice concerning Fort Cassin was published. At this time Professor R. P. Whitfield, Curator of the Geological Department in The American Museum of Natural History, described [3, pp. 300-345] a collection of fossils which had been made at this locality by Professors G. H. Perkins and H. M. Seely. This collection has been the object of interest and discussion ever since.

PALAEONTOLOGY.

The faunal aspect of the Fort Cassin fossils suggests that they are about Trenton and Chazy in age. A large *Isotelus* and several large nautiloids are enclosed in a black matrix similar to the Black River rock. A loosely coiled gastropod, *Eccyliomphalus,* lies half buried in a matrix of steel-gray appearance resembling the rock of the Chazy formation. A trilobite with genal spines from the thin shaly limestone is a type closely allied to the large trilobite at the top of the series, which is *Isotelus maximus* Locke, a form not known to exist below the Black River. The trilobite from the thin shaly limestone is comparatively small in its adult stage and most probably lived in the Upper Chazy seas. It is *Isotelus platymarginatus* Raymond (Plate XVII, fig. 2). This trilobite has been called *Isoteloides whitfieldi* [7, p. 36], which is supposed to occur in the Beekmantown formation. Its most striking characteristics are long genal spines and a semicircular pygidium. The cranidium has an acute angle anteriorily and is not rounded as according to the description of *Isoteloides whitfieldi.* An ontogenetic series of the pygidium shows that it varies but little in shape throughout life. During the young or nepionic stage the length of the pygidium increases in proportion to its width. The maximum length in proportion to width is in the neanic stage, when the pygidium is three-fourths as long as wide. The relation of length to width decreases slightly in the meta-neanic stage and continues in this proportion throughout its ephebic and gerontic existence. The axis of the pygidium displays slight annulations in young, exfoliated specimens and none in those forms which have not been exfoliated. In well preserved adults the axis is smooth and shows no annulations. The figure (Plate XVII, fig. 2) is a restoration based on several fragments. The species occurs abundantly in thin layers at the base of the thin shaly limestone.

During field work at Fort Cassin a few fossils not previously known from this locality were discovered. A specimen of *Streptelasma corniculum* Hall (Plate XVII, fig. 1, × 2) was found among the weathered stones on the shore. Another weathered specimen was *Actinoceras bigsbyi* Stokes (Plate XVII, fig. 3, × ½). These are typical Black River fossils. The cephalopod is seen in longitudinal section. The endosiphosheaths expand upward from the base in a siphuncle which is four and one-half inches across its widest part. On the reverse side of the specimen the steeply sloping septa may be seen, but the outer walls are absent. These fossils are not known to occur in the Beekmantown.

While the foregoing discussion is based on my field work and laboratory studies of collections which I made, the most important part of this study is founded on an examination of the Fort Cassin type and figured specimens in The American Museum of Natural History.

Of the forty-six species which are known to occur in the black siliceous limestone near the top of the Fort Cassin series, thirty-five were described as new by Whitfield [3, pp. 300-345;

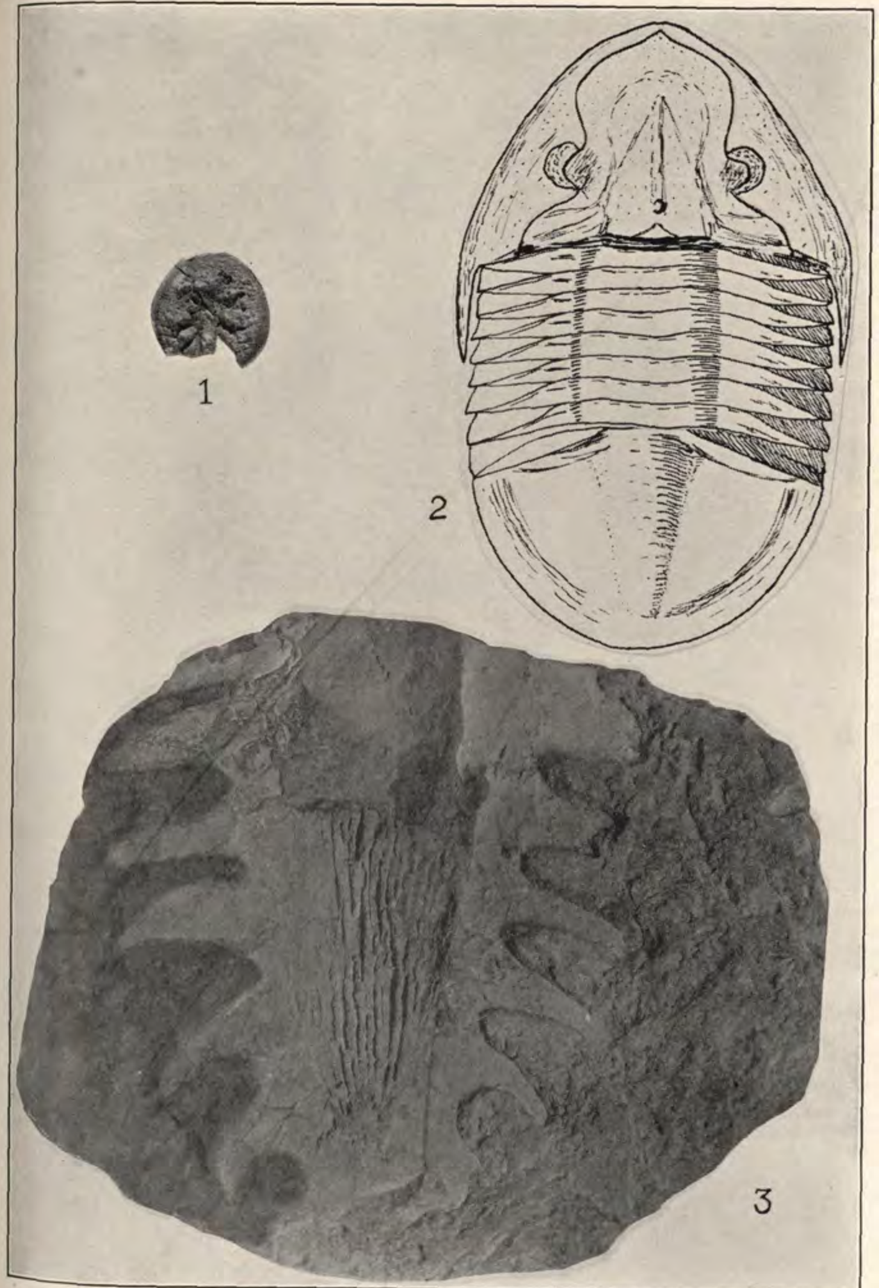


Fig. 1. *Strephelasma corniculum* Hale.
Fig. 2. *Isotelus platymarginatus* Raymond.
Fig. 3. *Actinoceras bigsbyi* Stokes.

4, pp. 29-39]. Twenty-nine of the new species occur only at Fort Cassin. The others are doubtfully identified [5] or are identified with species occurring in localities in Canada where the stratigraphy is not exactly determined. All of the species from the steel-gray bed were given new names. It is seen that out of fifty-two species found at Fort Cassin, forty-one were described as new. Such a discovery in this region would be doubtful. It is seldom, if ever, that we find from seventy-nine to one hundred per cent. of the fossils occurring in a formation in a fairly well-known region are new species.

It was discovered that many of the Fort Cassin fossils were strikingly similar to Trenton forms, and on close inspection some of them could be identified as species which occur only in the Trenton rocks. Chazy fossils were also found in the collection. An effort was made to compare each specimen with Trenton or Chazy species, and as the work progressed the evidence became more and more conclusive that the Fort Cassin type and figured specimens belonged to the Trenton and Chazy formations. Although this work is still in progress, a tentative list is given below with the old names at the left and the new names a little below and to the right of each name which has been changed.

BLACK RIVER.

Rhinopora prima Whitfield.
    Receptaculites oweni Hall. (Impression of central core.)
Dalmanella (?) *evadne* (Billings).
    Plectambonites sericeus (Sowerby).
Polytoechia apicalis (Whitfield).
    Dalmanella testudinaria (Dalman).
Syntrophia lateralis (Whitfield).
Archinacella simplex (Billings).
Clisospira lirata Whitfield.
Eccyliomphalus perkinsi (Whitfield).
Eccyliopterus volutatus Whitfield.
Eotomaria ? cassina (Whitfield).
Euconia etna (Billings).
    Clathrospira subconica (Hall).
Euomphalus ?? circumliratus Whitfield.
    Trochonema umbilicatum (Hall).
Fusispira obesa (Whitfield).
    Holopea paludiniformis Hall.
Helicotoma similis Whitfield.
Hormotoma obelisca (Whitfield).
    Fusispira subfusiformis (Hall).
Maclurites acuminatus (Billings).
Maclurites affinis (Billings).
    Maclurites crenulatus (Billings).

Murchisonia ?? prava Whitfield.
Hormotoma bellicincta (Hall).
Plethospira arenaria (Billings).
Holopea ventricosa Hall.
Plethospira cassina (Whitfield).
Raphistoma rotuloides (Hall).
Raphistoma compressum Whitfield.
Raphistoma hortensia (Billings).
Liospira vitruvia (Billings).
Scenella cassinensis Bassler.
Tryblidium ovale Whitfield.
Tryblidium ovatum Whitfield.
Cameroceras brainerdi (Whitfield).
Cyrtoceras ? acinacellum Whitfield.
Cyrtoceras confertissimum Whitfield.
Cyclostomiceras cassinense (Whitfield).
Poterioceras apertum Whiteaves.
Cyclostomiceras minimum (Whitfield).
Oncoceras constrictum Hall.
Eurystomites kelloggi (Whitfield).
Plectoceras ? undatum (Conrad).
Eurystomites rotundus Hyatt.
Plectoceras ? undatum (Conrad).
Orthoceras bilineatum Whitfield.
Spyroceras bilineatum (Hall).
Orthoceras explorator Billings.
Orthoceras multicameratum Emmons.
Orthoceras sordidum Billings.
Orygoceras cornuoryx (Whitfield).
Piloceras explanator Whitfield.
Protocycloceras whitfieldi Ruedemann.
Spyroceras bilineatum (Hall).
Schroederoceras eatoni (Whitfield).
Plectoceras ? undatum (Conrad).
Schroederoceras cassinense (Whitfield).
Plectoceras ? undatum (Conrad).
Trocholites internistriatus (Whitfield).
Plectoceras ? undatum (Conrad).
Tarphyceras seelyi (Whitfield).
Plectoceras ? undatum (Conrad).
Tarphyceras champlainense (Whitfield).
Tarphyceras perkinsi (Whitfield).
Plectoceras ? undatum (Conrad).
Asaphus canalis Conrad.
Isotelus maximus Locke.
Bathyurus longispinus Walcott.
Amphilichas trentonensis (Conrad).
Eoharpes cassinensis (Whitfield).

[redacted]

Nileus striatus Whitfield.
Ribeiria compressa Whitfield.
Ribeiria ventricosa Whitfield.

CHAZY.

Protorthis ? cassinensis Whitfield.
Dalmanella testudinaria (Dalman).
Protorthis ? minima Whitfield.
Dalmanella testudinaria (Dalman).
Eccyliomphalus lituiformis (Whitfield).
Hormotoma ? cassina (Whitfield).
Bolbocephalus seelyi (Whitfield).
Cf. Asaphus expansus Linnaeus.
Bathyurus perkinsi Whitfield.
Bathyurus extans (Hall).
Bolbocephalus ? truncatus Whitfield.
Bathyurus extans (Hall).

In the Princeton University collections I have seen *Bolbocephalus* Whitfield and *Isotelus platymarginatus* Raymond in the same piece of rock from the neighborhood of Plattsburgh, N. Y. (Loc., 133AA).

In conclusion, the foregoing evidence is offered to show that the rocks of Fort Cassin are not Beekmantown in age, but belong to the Chazy and Black River formations. In consequence, the upper part of Division D of Brainerd and Seely's Beekmantown, which has been correlated with the Fort Cassin rocks, must be other than Beekmantown in age; and it is suggested in this paper that it belongs to the Chazy.

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STUDIES IN THE GEOLOGY OF WESTERN VERMONT.

Third Paper.

CLARENCE E. GORDON.

TABLE OF CONTENTS.

INTRODUCTION.

The present paper reviews chiefly some of the field relations among the rocks that make up the Taconic range and its foothills in Vermont. The rocks everywhere have been greatly altered and deformed by pressure. Except for relatively small dikes of basic igneous rock, which are not infrequent in the region, there are no exposed intrusions. While petrographic study has not been made to determine if the rocks possess any characters that might logically be explained as the result of deep-seated injection of igneous rock, there do not appear to any such and the alteration which the rocks have suffered seems to be due to the dynamic agency of pressure alone.

The Taconic mountains of Vermont lie in the southwestern part of the state and form one of four major physiographic divisions. East of the Taconic range is a relative lowland which is known as the Vermont valley. The valley separates the range from the western scarps and hills of the Green Mountain plateau. At the latitude of Brandon the Vermont valley merges with the

Champlain lowland, a broad region lying between the Green Mountains and the Adirondacks, and occupied in its western portion by Lake Champlain.

These main physiographic features of western Vermont appear to be primarily of structural genesis. The Vermont valley and Champlain lowland are, broadly speaking, sunken areas due to differential movement between the rocks that underlie them and those that form the rock masses that border them on the east and west. These ancient structural features are materially emphasized by the work of erosion which has taken advantage of down-sunken areas of relatively soft rocks. But the deformations which were responsible for these major physiographic divisions were subsequent to earlier ones which were of a different kind and which now have expressions in various minor features of the landscape. These more ancient deformations were due to the action of powerful forces of compression which jammed, folded, overturned and ruptured the rocks. This particular class of secondary features may be identified in all of the main divisions of the region.

The major problem in the geology of western Vermont is to correlate the rocks within and among the different divisions. In this task one may not ignore the various disturbances and changes which the rocks have undergone. In view of the probable existence of common secondary structural characters among the rocks of these geographically closely related divisions one might hope to be able to apply a structural key to the problem of the primary relations of the various rocks.

There is fortunately not always a sharp difference between formations found in the different divisions of the region, but rather either identity or transitions may be shown to exist among the rocks in contiguous portions of these divisions. In cases where correlation must be made without the aid of fossils such relations are, of course, very important. In other cases a marked lithological difference between adjacent formations occurs and proves very baffling. It is well to remember that early deformations and later erosion have undoubtedly produced many of the irregularities of the present surface which are explicable only in the light of the disturbances which the rocks have suffered.

The western margin of the Green Mountain plateau is marked by a formation which has as its prominent member in many places a massive quartzite. This is usually associated with thinly-bedded quartzite or schist. In the northern part of the state the quartzite member is less prominent and may be replaced by quartzitic gneiss or schist. Quartzite and schist entirely similar to those which form the margin of the plateau make up scattered hills along the eastern side of the Vermont valley and Champlain lowland, or occur in the floor of the valley itself. These rocks, on the basis of fossils that have been found at a few places in them, are regarded as belonging to the lowest division of the Cambrian system.

In the valley and the lowland quartzite or schist are frequently associated with dolomite, or a formation composed of interbedded dolomite and quartzite, and in some places dolomite and in others the interbedded series apparently succeeds the quartzite conformably. Along the margin of the plateau dolomite also lies at places on the quartzite; but the dolomite has not been so extensively preserved as in the valley and the lowland. The rocks making up the floor of the valley are separated from those of the plateau by faults. There can be but little doubt that the dolomite was once more widely distributed over the quartzite and its associates within the plateau.

The dolomitic rocks so characteristic of the Vermont valley extend through the eastern portion of the Champlain lowland as far north as Hinesburg and Charlotte townships, where by changes in such features as color and thickness of beds they seem to grade into the magnesian and quartzitic rocks of the "Red Sandrock" series of northwestern Vermont.

In the Vermont valley the interbedded dolomitic and quartzitic rocks of the Lower Cambrian extend close to the bases of the rugged eastern slopes of the Taconic range. In the Champlain lowland the members of the Red Sandrock series extend west to the great fault along which the Lower Cambrian rocks have been elevated against the Ordovician beds of the lake series.

The distribution and characters of the various rocks that form the surface of the Champlain lowland have already been somewhat fully described by the writer (see second paper). In general it appears that east of the great fault that runs for miles east of the eastern shore of Lake Champlain an ancient Cambrian surface has been partly restored by processes of thrust and that on this surface there now rest younger rocks which are intricately involved with the older ones through folding and shearing. Fossils are scare and even when found are often suggestive rather than conclusive. Formations have been sheared out in the process of thrusting and imbrication and inversion of rocks have been produced in the same way until it becomes very difficult in many cases to predicate primary relationships from present conditions.

In the southern portion of the Champlain lowland members of the lake series of Ordovician rocks, carrying fossils, extend east to Weybridge, Cornwall and Sudbury and are intermingled at the present eroded surface in these townships with schists, phyllites and quartzite which are very similar to rocks found in the northern part of the Taconic range. These terrigenous rocks are, indeed, practically although not actually continuous from Sudbury through Whiting and Cornwall to Weybridge. And in the northern portion of the Taconic range, in western Sudbury township and in Benson and Orwell, members of the lake series carrying recognizable Chazy and Trenton fossils are intermingled in an irregular fashion with phyllites and schists like those of Cornwall and Weybridge. There is, therefore, not a sharp separation between the southern portion of the lowland and the northern part of the range, but the two merge into one another both topographically and geologically.

In the Champlain lowland the most southern outcrops of rocks that could be assigned to the Red Sandrock series occur in northeastern Bridport and northwestern Cornwall, forming the southern extension of the red quartzite of Snake Mountain into these townships. The black schists and lighter-colored phyllites which have been mentioned as forming the northern continuation of the rocks of Sudbury into Whiting, Cornwall and Weybridge lie on meridians about two miles east of the red rock of Snake Mountain. The red rock of Snake Mountain is supposed to be of Lower Cambrian age and according to the writer's view the schists and phyllites intermingled with the Ordovician limestones in Weybridge and Cornwall are probably of similar age. The questions of what was the primary relation and what is the present structural relation of the red rock to the phyllites may best be discussed later.

Along the western side of the Vermont valley, usually outcropping west of the general western margin of the dolomitic rocks that have been mentioned as forming such a large part of the hard rock surface of the valley, but sometimes occurring among the dolomitic series, are calcareous rocks belonging to a formation from which at various places throughout the valley and in the southeastern portion of the Champlain lowland marble has been quarried. The various rocks which are here correlated with one another are not always marble; but since they all seem to belong to the same general formation the latter may be conveniently called the "marble formation." These marble rocks of the western side of the Vermont valley extend westward into the Taconic range along the valleys of certain streams and at places through relatively high col-like passes. At the northern end of the range in Sudbury they seem to join at the present surface with fossiliferous rocks of the lake series; but south of Sudbury in the higher portions of the range they do not now extend very far west and indeed are usually fragmentary. Detached areas of various dimensions occur within the range all the way from Pittsford to Sandgate. The rocks of the marble formation have yielded fossils in only a few places. On the basis of such fossils as have been found and from other considerations the marble formation has been broadly classified as a part of the Ordovician system. Its probable structural relation to the dolomitic rocks that lie to the east of it has been discussed in the first paper under this title.

The rocks of the Taconic range and its outlying hills altogether make up a vast mass of metamorphosed terrigenous sediments of various kinds. While it is possible in a rough way over large areas to map some of these rocks as distinct from others, there is still a good deal of overlapping of the various kinds at the present surface. In the main portion of the range the rocks are prevailingly coarse schists with phyllitic, quartzitic and occasionally conglomeratic variants. These rocks have been called the "Berkshire Schist." West of the main range and some of its higher foothills the schist at the present surface is replaced over large areas by slates, but sharp boundaries are everywhere lacking. The broad area west of the main range and from which slates are so largely quarried, is known as the "slate belt." The slate belt has been described as largely formed of Lower Cambrian rocks with many extensive outliers of terrigenous Ordovician slates or schists. The Berkshire Schist has been described as lying above the marble formation and as belonging to the Ordovician system.

The assignment of certain terrigenous rocks of the slate belt to the Ordovician system has been on the basis of the discovery of fossils, mostly graptolites, at scattered localities, but large areas have been mapped as Ordovician in which only one or two fossil localities are known. In view of the relatively small number of fossil localities, question arises as to the extent of Ordovician terrigenous rocks in the slate belt. Large areas have clearly been mapped as Ordovician by reason of lithological similarity of the rocks to those which have yielded fossils. It often appears possible to make a lithological distinction between these terrigenous rocks which are called Ordovician and others which are called Cambrian; at other times separation in the field is not easy.

For the rocks of the slate belt which are called Cambrian lithological characters have also been extensively used; but fossil localities have been reported more frequently among such rocks.

The probable extent of Ordovician terrigenous rocks in the slate belt, and the relations which such rocks have on one hand to certain limestones carrying Ordovician fossils and, on the other, to the associated rocks of known or probable Cambrian age, are questions inviting further investigation. Only incidental mention will be made in this paper of these matters.

In the northern part of the slate belt detached areas of calcareous rocks, many of them with distinct fossils and others without, are associated with terrigenous rocks in apparently very much the same relations as that shown between the areas of calcareous rocks and their associated schists within the main range.

The Berkshire Schist is not a homogenous formation and it is difficult to distinguish some of its members from rocks found in the slate belt and from others found along the western margin of the Green Mountain plateau and in its foothills. It is not easy

to define the boundaries of the so-called Berkshire Schist. The geological age of the formation has been assigned from structural relations which it has seemed to have to other rocks. On the eastern side of the Taconic range the schist has been supposed to rest on the marble formation. Again, the schist has been described as showing transition, at some places west of the main range, into less altered terrigenous rocks that have been put in the Ordovician system on the basis of fossils which have been found in similar terrigenous rocks.

On the supposition that the schist is younger than the marble, it is surprising to note the absence of any similar rock over most of the Champlain lowland north of the Taconic range; for if the schist is of the age which has been claimed for it then it is difficult to imagine why, if such kinds of rocks as compose the Taconic range were there laid down above the limestone now represented by the marble, similar rocks were not deposited on Ordovician limestones over what is now the Champlain lowland. It is not easy to imagine that terrigenous rocks like the schists of the range were ever more widely distributed in the Champlain lowland above the calcareous rocks and were subsequently eroded. In the first place, there appears no good reason why such rocks should have been so extensively eroded over one part of the region and so fully preserved in another adjacent to it unless we assume that such rocks were very much thinner in one part of the region than in the other, or that the lowland was once at a relatively higher elevation than the Taconic region and that the present structural relation between the two was brought about after extensive erosion from what is now the lowland of rocks like those of the Taconic range. Neither history seems probable. Moreover, such rocks as are now found in the lowland and which can be correlated with the terrigenous rocks of the Taconic range do not appear to lie above the calcareous rocks with which they are associated, but on the contrary seem to be beneath them.

In the accounts which have been given of the occurrence of members of the marble formation at various places within the Taconic range the interpretation has been made that the marble is now exposed at the surface because of erosion of overlying schist. This may be the case at certain places, but at no place which the writer has seen is there any proof of it. In a region of thrust displacements it would not be extraordinary if an older schist formation was driven over a younger marble, but such a relation has not been observed within the range.

In northern Sudbury, and in Orwell, Whiting, Cornwall and Weybridge, members of the schist formation seem to emerge from beneath a covering of marbly or other calcareous rocks. In Sudbury, Orwell and Benson the field relations seem hardly to permit any other interpretation than that calcareous rocks of Ordovician age rest on a schist-phyllite formation. As will be explained more fully later there are reasons for thinking that the apparently inferior position of the marble on the east side of the Taconic range and at places within it is the result of displacements which have occurred between the calcareous rock and the schist. It may be noted at this place that definite sedimentary contacts are difficult to find and that the schists of the Taconic range and the oldest rocks of the slate belt seem nowhere to have their bases positively exposed.

The idea has been advanced that the so-called Berkshire Schist as a formation represents the entire Ordovician series of the slate belt, which is regarded as including various terrigenous rocks and limestones of Chazy and Trenton, and possibly Black River, age. This conception is difficult to support for many reasons.

For any further account of the relations among the rocks within the Vermont valley or the Champlain lowland the reader is referred to the other papers published under this title.

OBSERVATIONS MADE BY THE WRITER WITHIN THE TACONIC REGION.

General plan of discussion. As in previous papers, county and township names will be used as headings for purposes of description of the various parts of the region. Citation of localities will be based on the topographical sheets of the United States Geological Survey. It should be understood that the use of county and township names does not imply a complete description of the various geological features of the different towns named. The object of the paper is to discuss some apparently significant field relations that bear upon the interpretation of the structure of the Taconic region and upon the correlation of some of the rocks with those of adjacent or neighboring portions of western Vermont.

RUTLAND COUNTY.

Pittsford Township.

(Castleton topographic sheet.)

Location. Pittsford lies south of Brandon. It is bounded on the east by Chittenden, on the south by Rutland, Proctor and West Rutland, and on the west by Hubbardton and a small triangular portion of the township of Ira, which projects northward between it and the township of Castleton.

General description. The eastern part of Pittsford includes a portion of the western margin of the Green Mountain plateau. Its central part is occupied by a portion of the valley of Otter Creek. From the plain of the river the land rises gradually westward to the base of the steep eastern slopes of the Taconic range which extends through the western part of the township.

The rocks of the plateau margin and the Vermont valley in Pittsford have been only casually inspected. Those of the plateau join at the south with the quartzite and schist east of Rutland and northward join with those of Brandon. Coxe Mountain is the southern portion of an outlying ridge of quartzite and schist extending from Pittsford into Brandon. The ridge is separated from the steep margin of the plateau by the valley of Sugar Hollow Brook. The rocks of the ridge are interesting because, taken all together, they form an assemblage that in large measure has its counterpart in the rocks found in the Taconic hills in Sudbury and in other parts of the range. The valley of Sugar Hollow Brook is a synclinal trough modified by faulting and has its counterpart at several places north of Pittsford along the margin of the plateau. Numerous outcrops of dolomite, which has been described as lying above the basal terrigenous formation of quartzite and schist in the Vermont valley, occur along Sugar Hollow Brook as remnants of a large amount of similar rock that once filled the brook valley. The dolomite is at present only sparingly found in the high land east of Sugar Hollow; but it may be traced from the brook eastward up the steep slope of the mountain through a col to the upland. All the topographic and geological features around Sugar Hollow clearly indicate that the rocks forming the floor of the hollow and those of ridge west of it are dismembered parts of the plateau proper. Dolomite is found at places along the ridge west of Sugar Hollow, but for the most part has been eroded.

On the west the Coxe Mountain ridge slopes to the plain of Otter Creek. This western slope is drift covered. West of the creek is hilly land whose surface is formed of dolomite or interbedded dolomite and quartzite, and west of these by calcareous rocks belonging to the marble formation. Similar rocks undoubtedly underlie the plain along Otter Creek, for such rocks outcrop in Brandon on meridians occupied by the flood plain deposits in Pittsford.

The dolomite and interbedded rocks in the central and west central portion of Pittsford are counterparts of the dolomitic rocks of the eastern part of the town and presumably at some depth beneath the dolomitic rocks of the valley lies the terrigenous formation of the plateau.

Studies which have been made of the valley rocks in Brandon township have shown that the structural relations between the dolomites, which are probably of Lower Cambrian age, and the marble, which is probably of Ordovician age, are very complicated. In general the rocks are much involved through folding and thrusting. Satisfactory evidence of thrust overlap of the older dolomites on the marble may be seen in the neighborhood of Brandon. Many considerations could be offered to show the probability that the relations between the marble and dolomite all along the Vermont valley are not as simple as some descriptions of the region would have us believe.

South of Pittsford, partly in Rutland, partly in Proctor and West Rutland townships, is a ridge that separates a narrow valley which extends from Center Rutland village north through Proctor, and which has been called the Center Rutland valley, from another narrow valley which has been called the West Rutland valley. This ridge is largely made up of schist and at its northen end merges with the foothills of the Taconic range in the western part of Pittsford, which are composed of similar schists. Outcrops of marble occur at the eastern base of the ridge in Pittsford and the marble has been interpreted as passing beneath the schist. On the summit of the ridge near the boundary line between Pittsford and West Rutland are patches of calcareous rocks which seem to belong to the marble formation. These outcrops are not extensive and have been interpreted as interbedded members of the schist formation.

West Rutland valley is that occupied by the headstream of Castleton River. It extends into the southwestern part of Pittsford. The floor of the portion of the valley which lies in Pittsford is formed of the schist formation. But just south of the Pittsford line are apparently detached outcrops of marbly rock and farther south are the great marble quarries of West Rutland. According to the idea that the schist formation is younger than the marble, the absence of the latter in the portion of the valley of Castleton River that extends into Pittsford would be explained as due to the fact that erosion had not gone deep enough to expose the marble, while farther south it had. According to the same idea the marble would not be sought over the schist areas in the hilly land of western Pittsford, except as it might now occur at the surface as the result of irregularity of deformation which left the marble formation at certain places in such position that it was reached and exposed by erosion. The idea that there was any such irregularity of deformation would grow out of the circumstance that marble occurs here and there within the areas largely occupied by the schist formation, on the assumption that the schist is the younger rock. An alternative view, of course, is that small patches of marble or calcareous rock occurring within the schist are remnants of erosion of a formation that lay above the schist and that the latter is the older.

In previous papers, considerations have been offered in support of the view that a schist formation in all essential characters like that which forms the ridge between the Center Rutland and the West Rutland valleys and that which makes up the terrigenous areas in western Pittsford is actually subjacent to calcareous rocks which appear to belong to the marble formation of the Vermont valley. In southwestern Brandon and in Sudbury the field relations leave little doubt that the marble formation is superjacent

to the schist. The latter joins southward with similar schist in Hubbardton, which joins with that in the western part of Pittsford.

Within the schist area of western Pittsford one other outlying patch of the marble formation was found west of the band of outcrops of marble rocks on the west side of the valley along the schist border. This small area lies about a mile and a half west of Fowler, near the base of the eastern slope of Biddie Knob. The marble is plainly surrounded by the schist formation. A quarry, now unworked, has been opened in the marble at this place and considerable stone was apparently removed. It did not prove possible to determine whether the marble lies on the terrigenous rock and the field relations were too vague to warrant any generalizations on the basis of this outcrop taken by itself, as to relations of schist and marble.

Other than the features that have been elsewhere described for the terrigenous rocks of the Taconic hills and which could serve as a basis for correlating them with similar rocks in the eastern part of the Vermont valley and along the margin of the plateau, only one other thing was noted in Pittsford. One-fourth of a mile north of Butter Pond, and about two and a half miles north of the Pittsford and West Rutland line, near the summit of a hill west of the road to Fowler, layers of quartzite, schist and dolomite, the last subordinate but very evident, are infolded with schistose quartzite. The interbedded rocks just mentioned resemble strongly similar ones found at the base of the interbedded series of dolomite and quartzite in the eastern part of Brandon and elsewhere, and from the intimate relation which they have to the schist formation were regarded as furnishing additional evidence in support of the correlation of the schist at the west with similar rocks east of the Vermont valley.

Rutland and Proctor.

(Rutland and Castleton topographic sheets.)

Location. Rutland lies south of Pittsford and joins Mendon on the east, Clarendon on the south and West Rutland and Proctor on the west.

General description. North of the city of Rutland the surface rocks are quartzite with subordinate schist and dolomite and are the counterparts of similar rocks in the eastern part of Pittsford. These rocks north of Rutland have synclinal arrangement with dolomite on top. They are apparently separated from the rocks of Pittsford by a displacement across the strike, the Pittsford rocks being on the downthrow side. Northwest of the city of Rutland the quartzite and schist form a ridge known as Pine Hill. The eastern slope of this hill is largely quartzite, which frequently extends eastward at the surface to and across the road from Rutland to Pittsford Mills. The quartzite is succeeded eastward by the dolomite, but the quartzite bends round the dolomite at the north and joins with other quartzite on meridians farther east.

The quartzite of Pine Hill is interchangeable along and across the strike with a schist like that which forms the ridge between Center Rutland and West Rutland valleys. In Pine Hill the quartzite and schist each usually makes masses so large that they appear as distinct formations and have been interpreted and mapped as such and as of different age. The quartzite carries subordinate lenses of black schist not easily if at all distinguishable from the large schist masses. On the western slope of the Pine Hill ridge the quartzite in general now forms scarps above an apparently continuous band of the schist. East of Proctor the western slope of the hill descends over interbedded dolomites and quartzites which join with those that prevail around the village. Marble, however, outcrops at numerous places between the schist and the interbeddded rocks on the western slope of the hill.

The fact that a thrust at Pine Hill has thrown the terrigenous rocks against the marble and interbedded rocks that lie west of them has been recognized; but the schist has been interpreted as of younger age than the various calcareous and dolomitic rocks to the west of it and also as younger than the quartzite that lies above it. If this is the case then the absence of schist above the calcareous and dolomitic rocks of the valley in Pittsford, north of Proctor, must seemingly be accounted for by erosion. It is not easy to understand, if the schist is younger than the marble and normally lies above it in the Taconic range, why masses of schist as thick at least as those of the range should not once have covered the rocks now forming the floor of the Vermont valley in Pittsford and Brandon.

The terrigenous rocks of Pine Hill appear not to differ essentially from those which make up the ridge that begins with Coxe Mountain in Pittsford and extends northward into Brandon. In the latter ridge schist and quartzite are interchangeable along the strike and the schist has nowhere any association with the marble formation.

The relations of the dolomitic and calcareous rocks around the village of Proctor are very complicated and almost defy any attempt at description. Interbedded quartzite and dolomite and massive dolomite are intermingled with marble in an irregular manner and it did not seem possible to determine the structural relations from the present arrangement. Numerous outcrops of the interbedded series show the effect of strong compression in jammed and closely-folded beds, which often stand nearly vertical. Heavy masses of dolomite have apparently not been so strongly folded. The marble everywhere indicates great alteration. The inbedded rocks and most, if not all, the dolomite is correlated with the Lower Cambrian, as are similar rocks around

Brandon and in other parts of the Vermont valley. The marble is regarded as of Ordovician age.

South of Proctor village the Center Rutland valley narrows and bends somewhat to the eastward towards Center Rutland village, crossing diagonally the schist and quartzite north-northwest of the village. The calcareous rocks appear to run out at the surface southward and from relations shown by the terrigenous rocks east and west of Otter Creek near Center Rutland it is thought that these rocks form the hard rock surface beneath the mantle of surface deposits west of Center Rutland village. The schist which makes up the ridge between Center Rutland and West Rutland valleys outcrops at its southern end near the junction of the road from Center Rutland to West Rutland with the road to Proctor that runs along the west side of Center Rutland valley and these outcrops are on meridians only a little way to the west of those occupied by similar schist or by quartzite on the east side of the valley. The schist outcrops at many places along the road on the west side of Center Rutland valley, and at some places on contours nearly as low as the level of the plain of Otter Creek. The west side of the valley was searched for places that might show the marble passing beneath the schist, but such were not found. It seemed as though, if the schist lies on the marble, it would be found capping the marble at some places.

In the southern half of the schist ridge, west of Center Rutland valley, the eastern side emerges by fairly gentle slope from the lowland along the creek. West of Proctor village and on parallels somewhat north and south of it the eastern side of the ridge is abrupt and has much the appearance of a fault-line scarp, and was so interpreted.

No patches of calcareous rocks were found on the schist ridge west of Center Rutland valley, within the towns of Rutland or Proctor.

West Rutland Township.

(Castleton topographic sheet.)

Location. West Rutland joins Pittsford on the north and Proctor and Rutland on the east. On the south it joins with a part of Clarendon, but on this side is largely bounded by the township of Ira. Which also extends as a triangular area on the west and separates it from the township of Castleton.

General description. This township includes most of the so-called West Rutland valley celebrated the world over for its marble quarries. The name West Rutland valley is most often applied to the trough occupied by the headstream of Castleton River, north of the pass in the Taconic range through which the river flows westward, and to the southern extension of the Castleton River lowland to West Rutland town, but as a topographic feature the valley extends much farther south between the Taconic range on the west and the Danby-Clarendon ridge on the east.

The structure of the Castleton River valley north of West Rutland has been interpreted as anticlinal and the marble has been described as probably passing beneath the schist of the Taconic range. On the basis of a certain kind of interfingering of marble and schist at the northern end of the valley, where the marble runs out at the surface near the Pittsford line, it has been suggested that the anticline is probably made up of minor folds.

At best the field relations and minor structural features are far from being decisive and leave much to be guessed at, so that the general structure has been and may be surmised rather than proved. The present arrangement of the rocks and the distribution of the surface mantle are such that structure must largely be interpreted on the basis of probability, so that different views are possible according to the method of approach to the problem. If the view is taken that the schist is younger than the marble the structure would be explained in a different way from that which would proceed on the idea that the schist is older.

Certain structural features which have been cited in support of the view that the schist is younger than the marble do not seem to be convincing. In favor of the opposite view there are certain considerations which may not strike others as convincing. Once more to be noted is the apparent absence to any noteworthy extent of the schist formation over the lowland of Castleton River in the West Rutland valley. If the schist ever lay conformably on the marble within the area now occupied by the valley it seems as though there should be more evidence even in this narrow valley, of the resistant formation that forms such high ridges on the east and the west.

The assumption has been that the schist has all been eroded from the marble over most of the length of the valley and that the schist that now forms the valley floor just north of the Pittsford line now lies on marble which has not been exposed. In view of the apparent inferior position of the schist in Sudbury and Orwell to calcareous rocks that may be broadly correlated with the marble, the schist formation may be imagined as passing beneath the marble of the West Rutland valley. According to this view the schist floor of the valley north of the Pittsford line has been exposed by erosion of the marble and the reason why it is not found in the valley farther south would then be because the schist passes southward beneath the marble and emerges in the valley again only south of West Rutland town.

The marble formation outcrops within the valley from a point just south of the Pittsford line to a parallel about a mile south of West Rutland town. North of the town the outcrops occur along the eastern side. In the western part of the valley throughout the distance just mentioned a broad band of surface material separates the marble from the exposed portions of the schist at the base of the eastern slope of the Taconic range. What underlies the surface deposits is not known. Schist descends practically to the level of the plain of the river, along the road that runs on the western side of the valley, and near the Pittsford line forms one or more patches east of the road. If the marble formation has fairly regular anticlinal structure, with sufficient northerly pitch to pass beneath the schist in southern Pittsford it would seem as though the schist would not form a practically continuous outcrop as it now does, at such a low level, along the western side of the valley; but that it would be interrupted by the marble and that the latter would emerge at places from beneath the schist. Schist contact on marble seemingly might also be looked for in the northern part of the valley.

The most northern outcrops of calcareous rock that was noted in the valley occurs on the eastern north-south highway, just a little way south of the Pittsford line. It forms a knoll-like mass and on the north and west is surrounded by lower land. The field relations suggest that it is a portion of a larger mass of similar rock that has survived erosion rather than an inlier of marble in the schist formation. Unless minor folding is involved, which does not seem likely, if the schist is the younger rock, it should here occur at the topographic level of the softer rock, or even higher. The greater frequency of outcrops and abundance of marble along the eastern side of the valley may be accounted for through protection afforded the marble by reason of a certain amount of overlap occasioned by inversion of the eastern schist due to folding or thrusting rather than as the result of a normal capping of marble by schist. For, if the structure of the valley is that of fairly simple and regular anticline of marble overlain by schist, the marble should seemingly be preserved at similar levels, at places at least, along the western side of the valley as a result of protection given by the schist.

The eastern slope of the Taconic range which lies west of the West Rutland valley is in most places steep and often abrupt. As a whole, it offers strong suggestion of a fault line or zone along which the rocks of the West Rutland valley were dropped. The amount of displacement was not the same at all places. According to this idea the schist forming the floor of the valley in southwestern Pittsford has been disjoined from that forming the range on the west and was formerly at a relatively higher level. The schist east of the range occupies the downthrow side of a displacement.

If the indications of displacement offered by the topography may be accepted and the schist of the valley floor in southwestern Pittsford may be interpreted as just suggested, then it is possible without much difficulty to think of the calcareous rocks of the West Rutland valley as lying above the schist, as appears to be the case with similar rocks in the northern Taconic hills. The schist on the east side of the main range reaches down to such a low level that it is difficult to imagine that the marble is an inferior formation extending westward beneath it.

It might be argued, if the idea of faulting seems in any degree to be warranted, that purely topographic conditions could be discounted and that the valley rocks could be thought of as occupying the upthrow side of a displacement that dropped the schist now forming the Taconic range against a mass of older marble, and that it would be as easy to account for present apparent relations of the schist on the west side of the valley on such a view as it would on the assumption that the marble had been dropped from a higher level. But certain relations which have been observed farther north, in the western part of Brandon, not only strongly indicate that the marble is above the schist, but also that normal faulting has occurred between marble and schist so that marble in some places and schist in one place in particular now occupy an inferior level and seem to be on the downthrow side of a normal fault displacement.

In the Pine Hill mass of Rutland township the probability of a common age for schist and quartzite composing it seems very strong. The schist and quartzite formation along the western margin of the Green Mountain plateau, each of Pine Hill, with which the quartzite of Pine Hill joins in the southeastern part of Pittsford, shows quartzite interchanging with schist as in Pine Hill and in the eastern part of Brandon. It does not prove difficult, therefore, to find a reason for regarding the schist making up the present ridges to the west of the plateau, such as Pine Hill and that south of it in Clarendon, Tinmouth, Wallingford and Danby, both of which show no characters that are not understandable in such kind of terrigenous formation, as belonging to a formation which includes the massive quartzite. In Pine Hill and also in the ridge south of it there has probably been some differential movement within the terrigenous formation under pressure, because of the extensive development and massive character of the quartzite member. This may only be surmised, but certain relations between quartzite and schist in the northern part of the Taconic range suggest such a probability and such probability may be invoked to explain other relations within the Taconic range.

The fact of westward thrust at Pine Hill is reasonably clear, but the extent of the horizontal component of the thrust is not so apparent. It would not be difficult to offer explanation of the predominance of schist and the absence of any notable amount of quartzite in the ridge that separates the West Rutland and Center Rutland valleys, in contrast with conditions at Pine Hill, by assuming a considerable westward thrust at Pine Hill, with differential movement between quartzite and schist at Pine Hill, or vertical and horizontal variations within the terrigenous formation.

If the schist of the West Rutland intermediate ridge is to be correlated with a formation older than the marble, then its relation to the marble of the West Rutland valley is probably one of thrust overlap. There may or may not have been some differential thrust movement between the schist of West Rutland intermediate ridge and the calcareous rocks of the Center Rutland valley prior to normal faulting between them.

If the rocks of the West Rutland valley are on the downthrow side of a normal fault displacement, as has been suggested, it may be that the marble is faulted with the schist on the east in the intermediate ridge as well as with that of the main ridge, but it does not appear that present relations require such interpretation. It seems likely that the schist of the intermediate ridge was thrust against the marble and that such movement was antecedent to a normal fault displacement between the rocks of the main range and the valley and that when such displacement occurred, the marble and schist east of the range were dropped together. The schist of the intermediate ridge was probably overlain by marble, and possibly other rocks, like those that now occur east and west of it. Such may be the significance of the patches of marble that apparently lie on the schist at the summit of the ridge north and south of the Pittsford line.

It is easy to imagine, when the region was under compression and thrusting occurred, that the amount of differential elevation and lateral movement of the subjacent terrigenous formation was different at different places. The present relations would depend upon the extent of thrust displacement, upon the relative positions of the rocks after later disturbance by normal faulting, and upon further modification by erosion. In places where the calcareous and associated dolomitic rocks now form the surface, the thrust displacements may be observed among them. In other places by reason of the relation brought about by thrusting and the particular way in which erosion has operated, the displacement is now to be observed between schist and dolomite or between schist and marble. In still other places we may assume that on account of erosion of all the dolomite or marble, or both, depending upon the primary relations of such rocks to the terrigenous formation, the present surface intersects thrust displacements within the terrigenous formation and that at numerous places within the Taconic range and where the schist is exposed in the intermediated ridges of the valley adjacent terrigenous rocks are in displaced relations to each other. The fact of displacement among adjacent terrigenous rocks is difficult to demonstrate, but the probability of such condition is strong in view of the prevalence of thrusting among rocks in other parts of the region. In certain places, apparently because of thrust overlap and possibly later normal faulting, patches of calcareous rocks are still preserved as detached areas within the terrigenous formation.

Hubbardton Township.

(Castleton topographic sheet.)

Location. Hubbardton lies south of Sudbury and is bounded on the east by Pittsford, on the south by Castleton, and on the west by Benson.

General description. The terrigenous rocks of Hubbardton township are in largest part the southward continuation of those of Sudbury, with such variations in lithological characters and areal distribution as one might expect in a formation probably composed originally of a variety of sediments and probably deformed by repeated crustal disturbances. The present rocks are slates, phyllites, schists, quartzite and other metamorphosed sediments. In Hubbardton the slates, which are sparingly found among the other kinds in Sudbury, are prominent at some places in the western part of the town.

In the northwestern part of Hubbardton, north of Roach Pond and east of the road running north to Hortonville, are patches of limestone, much altered, but still showing traces of organic remains. This limestone is lithologically similar to rock found west of Hortonville in the adjoining town of Benson, and farther north in Orwell and the western part of Sudbury, and which carries fossils of Trenton age. In Benson the Trenton rocks are associated with Chazy limestone.

The outcrops of the limstone in Hubbardton are interrupted at the present surface by areas of blackish phyllite or schist just as are the similar rocks in Benson, Orwell and Sudbury. This schist, apparently because it is associated with Ordovician limestones and apparently also because it is thought to have lithological similarity to other terrigenous rocks of the slate belt which are in association with rocks that carry graptolites, has been mapped as belonging to the Ordovician system.

The primary relation of the schist to the associated limestone north of Roach Pond is difficult to determine. Bedded structure is not distinct in either limestone or schist, but both are strongly sheared with easterly dip. The limestone forms narrow strips between bands of schist, runs out at the surface along the strike and is replaced by schist, which frequently is at a lower topographic level than the limestone along the strike of the latter. The relations are not so clear between these rocks as they apparently are in Orwell and Sudbury, but on the whole the impression gained is that the limestone lies on the schist and has been involved in the deformation of the latter. The limestone seems to have been folded with the schist, probably with some differential movement between the two, attended by strong shearing with obliteration of bedding in both.

Except for the scattered areas in the northwestern part of the township, as just described, the only other exposures in Hubbardton of rock which could be correlated with the limestone near Hortonville occur in the hilly land a mile and a half due east of Beebe Pond. The locality is just east of a road that first runs east from Beebe Pond and then bends southward to join another road that runs from Hubbardton church northeasterly and swings southward to East Hubbardton monument. About one-third of a mile north of the latter road, on a side hill, are ledges of limestone which resembles the Trenton rock of Sudbury and Orwell and that around Hortonville. No fossils were found and the structural relations of the limestone to the schist which everywhere surrounds it is nowhere shown by contact. The general relations, however, leave no doubt but that the rock is in place. The topographic position of this limestone seemed clearly to be against any idea that it might be an exposure of an extensive formation lying beneath the schist which surrounds it, because similar rock apparently does not occur at lower topographic levels roundabout where it should seemingly be exposed if the schist lay normally above an extensive formation of limestone. It appears rather to be an outlier and to have been preserved because of favorable structural position.

On published maps of the slate belt the hard rock in the eastern portion of Hubbardton has been shown as belonging to the so-called Berkshire Schist and is represented as joining with the schist in the western part of Pittsford. The western boundary of the schist in Hubbardton is definitely drawn, but field examination shows that any clearly-defined separation of the terrigenous rocks along the supposed boundary is impossible. Along this boundary the schist, which is called Ordovician in age, is represented as meeting a terrigenous formation of Lower Cambrian age. The difficulties of having the schist rest on the Ordovician marble on the east side of the Taconic range and on the Lower Cambrian terrigenous rocks on the west side, and of having the marble rest on dolomite in the Vermont valley and the schist on a Cambrian terrigenous formation west of the main range, are met by assuming that the part of the Berkshire Schist mass that meets the Cambrian terrigenous rocks on the west corresponds to the upper part of the marble formation of the east side of the range and that the Cambrian terrigenous rocks on which the schist is supposed to rest at the west represents the Cambrian dolomite of the Vermont valley. Differences of sedimentation during the Cambrian and the Ordovician, amounting to lateral variation sufficient to account for such apparent anomalies, are further assumed as probable.

On the western side of the main Taconic range some of the rocks west of the assumed boundary of the so-called Berkshire Schist are placed in the Lower Cambrian on the basis of fossils which have been reported at several places and others are assigned to this system by lithological correlation with those which yielded fossils. Middle and Upper Cambrian rocks are not known and the schist is regarded as resting unconformably upon the Lower Cambrian formation. Thrusting and faulting are not ruled out, but the inclination has been to explain structure in other ways, where displacement may not be positively shown.

The accounts of the region which attempt to show the existence of a formation of Ordovician age forming the present surface of the Taconic range are obliged to proceed on certain assumptions founded on apparent field relations which may perhaps be interpreted in different ways. It is seen that the assignment of the schist of the Taconic range to the Ordovician system presents difficulties of satisfactory correlation with other rocks east and west of the range which are supposed to be of similar general age. The idea of variations in contemporaneous sediments may probably be invoked to explain certain relations within the region; but it seems doubtful if it may be applied as has been done in correlating the Berkshire Schist with the marble formation. Calcareous rocks, such as those composing the marble formation east of the Taconic range, do not occur along the western boundary of the so-called Berkshire Schist, as it seems they should do if the marble formation really dips beneath the schist on the east side of the range. No field relations between the Berkshire Schist and the terrigenous rocks of supposedly Lower Cambrian age which the schist is represented as meeting on the west of the Taconic range justify the notions that a displacement has dropped the schist and has, therefore, carried the marble down and that on account of such displacement there has been opportunity for schist and marble to be eroded from the "Cambrian" rocks of the slate belt subsequent to faulting. To keep the schist on the marble on the east side of the Taconic range and at the same time preserve the conception of an unconformity in the Taconic region between the Lower Cambrian rocks and the Berkshire Schist, in one case and between the Lower Cambrian terrigenous rocks and certain Ordovician limestones in another case requires a stretch of the imagination, although it might be contended that the effort to imagine such relations would not be greater than that required for other interpretations of the structure.

The calcareous rocks of known Ordovician age which are now present west of the Taconic range in various parts of the slate belt have apparently not been exposed by erosion of an extensive formation of overlying terrigenous rocks, although it is possible that in some cases limestones have been preserved by having been involved in the folding or shearing of underlying terrigenous rocks.

It is not argued that there are no terrigenous rocks of Ordovician age in the Taconic region, but it is suggested that a number of field relations make it possible to imagine that most of the so-called Berkshire Schist does not belong to that system. Even the terrigenous rocks in the western part of Hubbardton, which are distinguished on maps of the region from large areas of supposedly Lower Cambrian rocks, have apparently not been shown by fossils to belong in the Ordovician system, as represented, although they are thought to resemble rocks elsewhere in the slate belt which are associated with rocks carrying graptolites. If the schist actually lies, as it seems to, beneath the calcareous rocks in western Hubbardton, in the absence of fossils it may be questioned if much of such schist is of Ordovician age.

The lack of sharp separation between Berkshire Schist and so-called Lower Cambrian rocks is apparent along many surface sections from east to west in the town of Hubbardton and in townships to the north and south. The Lower Cambrian formation shows many variations throughout the areas which have been mapped as occupied by it. Slate, phyllite and schist, each showing in many places segregations of quartz, which probably represents sandy beds in muddy sediments of various kinds, and massive quartzite, pass into one another at the present surface. There seems to be no particular order in the distribution of the rocks, except that in general the finer-textured slates and phyllites seem more prominent at the west and the coarser varieties at the east. Phyllitic rocks similar except for slightly greater crystallinity to many rocks of the slate belt occur east of the supposed western boundary of the Berkshire Schist and are associated with other rocks which it did not seem difficult to correlate in their lithological features with similar rocks in areas farther west.

Over the eastern part of Hubbardton there seemed indeed to be an intermingling at the present surface of phyllites, schist and quartzite, such as has been described for the Taconic hills in Sudbury and the western part of Brandon. Areas of pure massive quartzite occur in Hubbardton as in the western part of Brandon, but a more common variety of coarse rock is an impure schist or graywacke quartzite which is frequently marked by segregations of quartz apparently resulting from sandy layers or lenses. Quartz segregations are, however, frequent in the finer-textured rocks of the Taconic region.

At Zion Hill, two-thirds of a mile southwest of East Hubbardton monument, beds of massive quartzite, in all perhaps 60 to 75 feet thick, lie above green and purple slates or phyllites. The hill has abrupt cliffs on the east, north and west. The beds form a small synclinal fold. East of the hill similar beds seem to have an anticlinal arrangement. The abrupt northern side of the hill faces a gentle slope extending from the base northward to the East Hubbardton road. The massive quartzite may have thrust displacement relation to the rocks that surround it. While the structure is not clear, the quartzite is regarded as an integral part of the general terrigenous formation. Similar quartzite occurs at Barker Hill two miles to the south, in Castleton, on meridians closely approximating those occupied by the quartzite of Zion Hill.

The heavier quartzite members of the terrigenous formation must have resisted deformation much more than the finer sediments. The latter as they are now shown in the quarries of the slate belt may be seen to have been jammed into close folds, overturned and strongly sheared. If one makes no age distinction among the terrigenous rocks of Hubbardton and other areas in the Taconic region as well—at least, for the areas that have been mapped as Berkshire Schist and Lower Cambrian—the surface rocks over a large area seem to compose a formation that is homogenous in its heterogeneity, consisting of the metamorphic derivatives of many varieties of sedimentary rocks. These may be thought of as having behaved under the compression, which their structure shows they at one time experienced, more or less according to the features of their primary structure. Under erosion these rocks also behaved according to their primary natures, but secondary structural features were controlling factors as well.

It is evident from a study of these rocks in the field that they have suffered extensive denudation. The only suggestion which we now have, from the areas over which they now chiefly form the surface, of what may formerly have lain above them, is apparently found in the scattered remnants of limestone that appears to be of Ordovician age, and possibly in certain terrigenous rocks whose actual surface extent is very uncertain.

If one may generalize from the structure shown by the muddy rocks of the slate belt it appears that in general the effect of compression was to produce numerous minor folds, but it seems probable that the more fully competent character of much of the terrigenous rock to resist compression would have introduced dislocations of the nature of thrusts and that there would have been much irregularity on account of primary irregular distribution of the different kinds of terrigenous rocks. But one finds it difficult or impossible to locate thrust contacts with certainty in this much dissected region.

Castleton Township.

(Castleton topographic sheet.)

Location. Castleton lies south of Hubbardton and between Fair Haven on the west and Ira on the east. It is bounded on the south by Poultney.

General description. The same general assemblage of terrigenous rocks that forms the surface over most of Hubbardton township makes up the hard rock surface in Castleton. In this township fossils have been reported from only a few places and correlation of the rocks has been, therefore, almost wholly on the basis of lithological resemblances to other rocks of the region which have yielded fossils or whose structural relationships have been interpreted as indicative of their age. The Berkshire Schist is represented on maps of the region as extending south from Hubbardton into the eastern part of Castleton, where it is shown as joining eastward with the schist of Ira, which joins with that of West Rutland. As in Hubbardton the schist in Castleton is represented as meeting along a fairly definite boundary a formation of terrigenous rocks which are assigned to the Lower Cambrian system.

A relatively narrow band of slates has been described and mapped as belonging to the Ordovician system and as extending in the midst of the Lower Cambrian rocks in a general north-south direction through West Castleton, west of Lake Bomoseen. From some of the rocks included in this belt, graptolites have been reported and the forms are thought to leave no doubt as to their Ordovician age. The structural relation between the rocks that are called Ordovician and those which are called Cambrian is not clear. As is the case all through the slate belt, the rocks have been much disturbed. From the structure shown in certain ledges the "Ordovician" slate is believed to have synclinal structure and the Cambrian rocks east of it are described as probably being overturned to the west, or faulted.

The various other terrigenous rocks of Castleton show no more regularity in distribution than do those of Hubbardton and field inspection shows that the various kinds pass into one another at the present surface. They present puzzling relationships. The boundary between Berkshire Schist and Cambrian rocks seems no more clearly defined than in Hubbardton.

While the rocks which have been called Cambrian are largely terrigenous in character it should be noted that in Castleton and in other parts of the slate belt there are within the terrigenous formation beds of calcareous rock which carry Lower Cambrian fossils. The Lower Cambrian terrigenous rocks are slates, phyllites, schists and quartzite, but sometimes associated with quartzite are quartz conglomerates and not very different conglomeratic rocks are also found associated with quartzite in areas mapped as Berkshire Schist.

Because of their heterogeneity and present arrangement any detailed description of the distribution of the various rocks of Castleton would be difficult, but some special features should be noted.

Slates are prominent in the western half of the town, but are more or less intimately associated with other kinds of rock. At the east the rocks are prevailingly coarser and less pure and are now represented by phyllites, schists and less frequently by quartzite. A quartzite like that making up Zion Hill in Hubbardton occurs two miles south of it at Barker Hill in Castleton. The two may be parts of a once continuous mass or each may represent a lens-like mass of quartzite within other sediments.

A mile east of Lake Bomoseen, just south of the Hubbardton line, is a prominent scarp known as Wallace Ledge. The face of the scarp shows a considerable thickness of greenish slate, or phyllite, capped by a bed of quartzite perhaps 25 feet thick. Overlying the quartzite is phyllite similar to that beneath it. From the road west of Sucker Brook the quartzite layer was seen to be much folded.

The conditions at Zion Hill and Wallace Ledge seem to give some clue as to the primary arrangement of some of these terrigenous rocks. More or less sandy layers or lenses were interstratified with muddy rocks and apparently the thickness of the sandy rock varied at different places. It seems likely that these sandy layers underwent a certain amount of induration prior to folding of the various rocks and when brought under compression were not easily deformed and probably in many cases were fractured with displacement. The quarry hole at Cedar Point on the west shore of Lake Bomoseen shows an overturned syncline with the axial plane nearly flat, dipping slightly to the east. It is easy to imagine a rock mass riding forward along a thrust plane on the overturned limb of such a fold.

On the meridan of Wallace Ledge and two miles south of it, at Bull Hill, the green and purple slates are quarried.

Bird Mountain. In the southeastern part of the township, but partly in the adjoining towns of Ira and Poultney, is a singular pile known as Bird Mountain. In its outlines it has same resemblance to Zion Hill in Hubbardton except that it is larger and has a high scarp facing to the south instead of to the north and has a northerly pitch. A coarse talus lies at the bases of the cliffs that bound the mountain on the east, south and west and sloping away from the talus piles on the three sides mentioned is boulder drift which conceals the underlying rock. Along the road west of Bird Mountain are green and purple phyllites quite similar to rocks found farther west and similar rocks peak through the drift along the road east of the mountain.

The rocks of the mountain were inspected on the southern face above the talus slope and on the eastern side and the summit. They consist of fine-grained conglomerates, quartzites and sericitic phyllite and are interbedded. Judging from the rocks seen in the southern face of the mountain and on its summit the conglomerate is not extraordinarily abundant. From its interbedded character it is best interpreted as intraformational. Petrographic analyses of the conglomerate have shown in addition to quartz

pebbles others of crystalline limestone and some of quartzite with calcareous cement, sources for which are problematical.

Rocks similar to those at Bird Mountain occur about two miles south by west of the mountain in the town of Poultney and will be briefly mentioned in the description of that township.

The presence of a conglomerate like that of Bird Mountain and the areas farther south suggests erosion of a land surface not very remote from the place of its deposition, but it does not necessarily indicate any great hiatus. Conglomeratic rocks, usually less extensively developed, are found at other places in the Taconic region, sometimes closely associated with other rocks carrying Cambrian fossils. In the older rocks now found at the surface in various parts of western Vermont there is strong indication that a variety of conditions prevailed during their deposition. There seems to have existed in Lower Cambrian time a shallow trough bordered by a land mass with somewhat irregular coastline. In a part of this trough accumulated the material now represented by the Sandrock series of northwestern Vermont. Along the border of the land at different places the conditions were often favorable for the formation of thick masses of quartz sand with or without subordinate inclusions of impure muds. At other places rivers apparently built out deltas of diversified sediments which were spread out not far from the land in the shallow sea. Oscillations were not infrequent. For the most part terrigenous sedimentation prevailed in the delta accumulations, but sometimes calcareous beds were formed during encroachment of the sea and apparently at a time of greater submergence of the terrigenous deposits of the delta areas, dolomitic rocks, like those which were laid down in parts of the sea into which rivers did not carry much land sediment, were deposited, to some extent at least, on the earlier delta deposits. All parts of the floor of the sea in which these varied contemporaneous deposits were formed apparently oscillated from time to time and in many places the sediments were exposed to the air and more or less oxidized. Many physical features of the rocks point to shallow water conditions during their formation and to periodic oscillation of the sea bottom. In the deltas, probably owing to elevation landward, coarser deposits were carried by streams away from shore and distributed on the delta surface.

The field relations of the rocks of Bird Mountain make it difficult to separate them from the other terrigenous rocks with which they are associated. All seem to be part and parcel of the same formation. Although the coarser sediments of Bird Mountain and other localities probably mean a time of elevation and erosion, in a general sense they were probably contemporaneous with the other rocks of the region. The ideas just presented are contrary to the views of other students. The idea has been entertained that the Bird Mountain rocks indicate a greater hiatus than that just suggested and represent a somewhat extensive formation, now largely eroded. The rocks have been assigned to different systems; first, to the Upper Silurian (Silurian), and later to the upper part of the Ordovician. There are good reasons for thinking that rocks like those of Bird Mountain were once somewhat more extensive than at present, but it does not seem likely that they were ever widespread. It seems reasonable to regard them as somewhat local developments of coarse rocks in a region which at other places shows similar rocks as normal variations in the process of accumulation of terrigenous sediments in a shallow sea and in which both the sea bottom and the adjacent land underwent oscillations of level. Even if a group of sediments like those of Bird Mountain marked a considerable time interval separating portions of one system it seems as though it should be more widespread than it is today; although the probability that the hiatus in such a case would not everywhere be represented by conglomerates and corse sandstones must be recognized.

By implication the validity of the term, Berkshire Schist, as the name of a formation distinct from various other rocks of the region has been questioned in the preceding pages and the suggestion has been offered that most of the rocks found in areas that have been mapped as Berkshire Schist are possibly the time equivalents in a broad sense of rocks found in areas mapped as Lower Cambrian within the slate belt and of rocks found in the western marginal portions of the Green Mountain plateau and in the intermediate schist ridges of the Vermont valley west and south of Rutland. This idea takes into account probable primary variations within a formation of probably contemporaneous and diversified sediments as well as characters that would appear after regional metamorphism of a mass of rocks showing such original differences. Little direct evidence is available for the age of most of the rocks in question. Recognition has been given by other students to the fact that within areas mapped as Berkshire Schist rocks occur which are similar to some which are found in nearby areas that are mapped as Lower Cambrian, but the further notion has been that these are instances of parallel development and not indications of kinship. The possibility of such conditions must be admitted; but in the writer's view the field relations do not seem to support the interpretations of the relations of the schist and associated rocks that have been offered and bear away from the commonly held idea that the schist is of Ordovician age.

Ira Township.

(Castleton topographic sheet.)

Location. This township is irregular in shape. Its wedge-shaped northern portion touches the southeastern part of Hubbardton and the southwestern part of Pittsford. On the west it is bounded by parts of the townships of Castleton, Poultney and Middletown, and on the east by parts of West Rutland and Clarendon. On the south it borders a part of Tinmouth township.

General description. The surface rock in Ira, except for a very small area of altered limestone which will be described beyond, is of terrigenous character and has been mapped as part of the Berkshire Schist. Outcrops were examined along a section crossing the township two miles north of Castleton River, along the road east of Bird Mountain, and along the roads and on the hillsides north, west and south of the village of Ira.

North of Castleton River, a mile south of Ransomvale, a road runs east from the main Castleton-East Hubbardton road and crosses the range through a saddle to the West Rutland valley. The rock which outcrops frequently in the clearing along this road on top of the range is a crupled impure schist which often carries segregations of quartz. On the western slope, in the bottoms of brook gulleys in the drift, outcrops of greenish schist were noted. This rock closely resembles the phyllite or schist along the road east of Bird Mountain to the south of Castleton River.

The terrigenous rocks north, west and south of the village of Ira show the usual types found within the Taconic range and the intermediate ridges east of it. They consist of impure quartzitic schists, rusty sericitic schists and black schists and, as a whole, give an assemblage which in comparison with the surrounding region shows no distinctive features.

The limestone at Day's quarry. A little more than a mile northwest of the village of Ira, on the farm of D. D. Day, is a small patch of altered limestone which has been quarried for lime. The area occupied by this rock is probably not more than 400 feet wide and 1,000 feet long. The limestone is surrounded by the characteristic terrigenous rocks of the region.

Just north of the quarry the weathered surface of the limestone shows numerous sections of gastropod shells which are not well enough preserved for positive identification, but which strongly suggest some form of *Maclurea.*

Limestone and schist are close together in some places, but only one contact was seen. On the east side of the quarry, near the kiln, the marble lies against the schist and above it. It could not be determined whether the relation between marble and schist is primary or secondary. It did not seem probable that the marble is an inclusion in the schist. If this were the case, seemingly there should be more frequent occurrences. That the marble has been exposed by erosion of part of a conformable mass of overlying schist seemed equally improbable, for such a view would imply a somewhat extensive mass of marble overlain by schist, and if such were the primary condition it would seem that other portions of the marble should have been exposed by erosion at places not very distant.

The marble at Day's quarry is a graphitic rock. It is singularly isolated from any other exposures of similar marble. It occupies a sort of pocket in the terrigenous formation. The contact shown near the kiln may not be a normal one, but it offers direct evidence that the marble rests on the schist. At no place was the latter found lying above the marble. In view of the small exposure and isolation it seems likely that the explanation of its preservation is to be found in the deformational changes which the region has experienced.

Poultney, Middletown, Tinmouth, Wells, Pawlet and Danby Townships.

(Castleton and Pawlet topographic sheets.)

General description. The townships mentioned in the heading make up the southwestern portion of Rutland County. Their relative positions will be mentioned as the special or general geologic features of each is described. The rocks in these townships were examined chiefly along the roads that traverse them and to some extent in the woods and open fields.

Poultney. This town lies south of Castleton. The hard rocks forming its surface have been described and mapped as belonging partly to the Lower Cambrian terrane and partly to the Ordovician system. Those classed with the Ordovician include the so-called Berkshire Schist of the eastern part, which is regarded as the southward continuation of the same formation in Castleton, and some other terrigenous rocks of the western part from which at one or two places graptolites have been reported. The so-called Lower Cambrian terrigenous rocks border the schist on the west and surround the other "Ordovician" rocks.

The so-called Ordovician terrigenous rocks in the western part of the town seem indeed to have in many cases lithological characters that serve to distinguish them from the purple and green slates and other types that are called Lower Cambrian, but in the Taconic region it is hardly possible, in most if not in all cases, to say what the nature of the boundary now is between rocks that are thought to be of one age and those that are considered to belong to a different system. The boundaries of the different rocks have clearly been drawn in very large measure on the basis of lithological features. But as the writer has elsewhere shown the field relations among terrigenous rocks similar to those of the townships so far discussed are in many places often of such character that it is impossible, in the absence of the direct evidence afforded by fossils, to make any separation with respect to their age on the basis of lithology. Furthermore, different kinds of rocks often show such intermingling and such kind of intermingling at the present surface that they appear to belong to one system rather than to two.

The Berkshire Schist in Poultney seems to be no more sharply defined from the so-called Lower Cambrian than it is in Castleton and Hubbardton.

In the northeastern part of Poultney are a number of high hills showing prominent scarps on the east and in several places. The rocks of these hills are quartzite with interbedded conglomerate and schist. They seem to be the southward extension of the rocks of Bird Mountain, from which they are separated at the present surface, but with which they may once have been continuous. These hills are surrounded by green or purple phyllites which frequently carry thin beds of quartzite. Northeast of Hampshire Hollow the structure of the heavy quartzite and associated rocks suggests that they are all a part of the same formation and that they have been deformed together. Southwestward the quartzite and associated conglomerate disappear at the present surface and their places are taken by the schist. Old Knob, a hill lying between Fennell and Hampshire Hollows, is a mass of green and purple phyllite, but southwest of the hill, east of Fennell Hollow road, is black schist which does not seem to differ from rock which has been mapped for other areas as of different age. West of Fennell Hollow is schist, much of which is black, and which has been mapped as Lower Cambrian. East of Old Knob, at the northern end of Hampshire Hollow, the surface rock east of the road is often a coarse graywacke schist, which has been mapped as Berkshire Schist. Irregular sections across the strike of the rocks north of East Poultney give a sequence from blackish schists through green or purple varieties to coarse sericitic graywackes and there are no clearly marked boundaries among them.

The only calcareous rocks which were seen in Poultney were found one mile south of Spaulding Hill, south of the Moss Hollow road. An exposure of sheared dolomitic limestone, hardly more than thirty feet square, seemed to be in place, but there is much uncertainty about it.

Middletown. The rocks of Middletown offer no distinctive features. They have been mapped as belonging to the Berkshire Schist formation. So far as examined along the main east-west road from Middletown Spring to Pawlet they are in general like the rocks called Berkshire Schist in the surrounding townships and show very similar variations.

Tinmouth. In the township of Tinmouth, which bounds part of Middletown and part of Wells on the east, were found two detached areas of altered limestone surrounded by the schist formation. One of these lies about a mile south of the Ira township line and one-third of a mile east of the Middletown boundary, north of the road from Middletown Springs to Tinmouth village. The rock is a sheared limestone, much like that which occurs in many places in the northern part of the Taconic range in Sudbury. The limestone forms low-lying ledges of varying but always small dimensions, surrounded by drift, and would easily pass unnoticed except in systematic search. The rock is in place without any doubt and the area occupied by its outcrops is perhaps several acres in extent. The conditions are such as to suggest that similar limestone may underlie the drift in other places within the Taconic region. Probably the actual area covered by the limestone at this locality is somewhat larger than that over which its outcrops now appear. The rock has been altered almost to the condition of a marble. It is apparently everywhere surrounded by the schist formation. The nearest outcrops of similar rock are nearly a mile to the east along the western side of Tinmouth valley, where at several places the so-called marble appears to lie above the schist, as previously described by the writer.

Another isolated area of altered limestone was found about five miles southwest of that just described. It lies west of the mountain called The Purchase, and one-third of a mile north of the Danby line. The limestone at this locality, like that on the Middletown Springs-Tinmouth road just described, is surrounded by drift and its outcrops are intermingled with the surface material. The actual area and boundaries of the calcareous rock could not be determined. A brook south of the principal outcrops of the limestone cuts deeply into the drift without exposing the hard rock. The limestone forms numerous outcrops. It is certain that it is not a part of the drift. The nearest outcrops of a similar limestone occur three miles to the east on the western side of Tinmouth valley.

Wells. This township lies south of Poultney along the New York border and is bounded on the east by Tinmouth and on the south by Pawlet.

Most of the hard rock surface has been mapped as belonging to the Berkshire Schist. West of the schist is a band of slates which has been represented as part of the Lower Cambrian and west of this band, along the state border, a strip is shown which is regarded as made up of Ordovician terrigenous rocks like those intermingled with the purple and green slates of other parts of the slate belt.

The eastern and central portions of the township have a rugged surface which joins eastward with that of Middletown and Tinmouth. This more rugged portion is bounded on the west by a series of prominent scarps which lie approximately along the same north-south line. This scarp topography continues southward into Pawlet in the steep western faces of Simonds, Cleveland and Burt Hills, and northward is represented by a steep scarp on the west side of St. Catherine Mountain in Poultney. Lake St. Catherine and its southward extension, known as Little Pond, lie west of this line of scarps.

The fact was not mentioned in the descriptions of Hubbardton and Castleton, but a broken line of scarps extends from Sudbury on the east side of Keeler Pond in Hubbardton and southward past Beebe Pond to Lake Bomoseen in Castleton. North of Castleton the scarps are interrupted by gentler slopes and are always of lower altitude than those at the south, east of Lake St. Catherine. In the topography and in the arrangement of these water bodies there are strong suggestions of displacement along a zone extending from the hills in Sudbury into Pawlet and that the different ponds and lakes lie in structural basins. There is indication of faulting also on the southwest shore of Lake Bomoseen and in the hilly land west and northwest of the lake.

There are in fact at many places in the Taconic region scarps bounding the higher elevations which suggest displacement. Some of these scarps face to the east, others to the west, while others run from east to west across the strike of the rocks. Cliffs and scarps contribute very appreciably to the topographic outlines of the Taconic region.

In most cases where scarps suggest old fault lines or where faulting may be suspected for other reasons, the fact of displacement cannot be demonstrated because of the similarity or nature of the rocks that lie in juxtaposition. If lines were drawn in on a map of this region to represent all the probable displacements within the mountains and their foothills they would undoubtedly be viewed with suspicion, but an inspection of the territory itself would probably be convincing to many observers.

At the northern end of the range, in southwestern Brandon and in Sudbury and Orwell, as has elsewhere been explained, faulting along and across the strike may be shown to have been a frequent occurrence. In this part of the range the fact of displacement may be more readily appreciated because of lithological differences between the rocks involved. On both the east and the west sides of the hills in Sudbury the limestone and schist often clearly lie in faulted relation to each other. In some places it may be observed that the calcareous rock lies above the schist and that on the downthrow side of a displacement, erosion has removed the calcareous rock at some places, thus giving limestone at one place and schist at another lying against the schist of the upthrow side. The calcareous rock has been partially or wholly eroded from the schist of the upthrow side. Moreover, a study of surface sections from east to west across the northern end of the range seems to show that fault lines occur within the schist of the range and that some of the scarp and basin topography of the present surface are primarily due to ancient displacements.

It seems very probable that the scarp topography that has been described above as extending from Sudbury to Pawlet along the chain of ponds that were mentioned, represents a prominent zone of fracture in a region marked by subordinate displacements at many places. That the displacements which seem to have occurred in the Taconic region all belong to the same episode of disturbance is not certain. Some of them may have occurred at the time when the structural outlines of the Vermont valley and Champlain lowland were laid down and others may have occurred later.

Pawlet. The rocks of Pawlet are the southward continuation of those of Wells. In Pawlet, and in the township of Rupert south of it, the Berkshire Schist of the eastern part has been represented as contiguous at the present surface with other Ordovician terrigenous rocks of the western part, and in Rupert certain grits which have been described as carrying fragments of various rocks and as associated at places with graptolite shales are called Ordovician and further described as showing transition into the Berkshire Schist.

Near the southern boundary of Pawlet, west of the road from Pawlet village to Dorset village, about two and a half miles south of the former, and also a little farther north on the east side of the road, are patches of altered limestone intermingled with and surrounded by the schist formation. The calcareous rock at some places can be seen to have been jammed into small, closely-compressed folds and to have been strongly sheared. The limestone has general resemblance to that which has been described in preceding pages as occuring as probable outliers within the schist. In Pawlet the primary relation of limestone to schist is obscure. The two rocks were apparently simultaneously involved in some deformation due to compression.

Danby. Danby township lies east of Pawlet. Its western half includes a part of the Taconic range. In the eastern part the northward extension of Tinmouth valley separates the main range from Danby Hill, which is the northward extension of the Clarendon-Tinmouth ridge which separates the Clarendon River-Tinmouth valley from that of Otter Creek.

The Clarendon River-Tinmouth valley, including its southward extension into Danby township, seems to have a structure like that described for the West Rutland valley. It appears to occupy a downthrow position with respect to the main range on the west. It and the ridge that bounds it on the east are subordinate topographic features of the major or Vermont valley.

The subordinate ridge east of Tinmouth valley is composed chiefly of schist and massive quartzite like that which makes up Pine Hill north of Rutland and the schist and quartzite have much the same relations to one another in the Danby-Clarendon ridge that they do in Pine Hill. They seem to be parts of the same formation.

East and west of Danby Hill are interbedded dolomitic and quartzitic rocks like those found so widely distributed throughout the Vermont valley.

Along or near the road on the west side of Tinmouth valley, in Danby and northward in Tinmouth and Clarendon, are intermittent outcrops of marble which along some meridians on which they occur are interrupted by exposures of schist. In some places the marble gives the distinct impression of lying above the schist.

On the ridge intermediate between Tinmouth valley and the main Otter Creek valley the quartzite-schist formation is apparently overlain by patches of marbly limestone. Some of these occur in Danby and others just north of the Danby line in Tinmouth and Wallingford.

The southern part of Danby township includes the northern slopes of Dorset Mountain, on which are various exposures of marble, some of which are quarried. An east-west fault zone bounds Dorset Mountain on the north. The displacements which separate Dorset Mountain and Danby Hill apparently belong to the episode of deformation during which were formed the structural outlines of the Vermont valley, and were contemporaneous with those which "dropped" the rocks of Tinmouth and West Rutland valleys.

A small area of "marble" has been described as occurring within the main range in the western part of Danby township, to the west of Dutch Hill, between it and Harrington Hill, but this was not found by the writer.

Dutch Hill and Mount Hoag in the western part of the town show scarps like those in the hills to the north and south.

The terrigenous rocks in the western part of Danby are like those in other parts of the Taconic range and the schistose types do not differ from those found associated with the quartzite in the intermediate ridge east of Tinmouth valley.

BENNINGTON COUNTY.

Dorset Township.

(Pawlet and Equinox topographic sheets.)

Location. Dorset lies south of Danby. It is bounded on the west by Rupert, on the south by Manchester, and on the east by Peru.

General description. The main portion of the Dorset Mountain mass lies in this township. The mountain forms a physiographic outlier of the Taconic range and juts so far east across the Vermont valley that its eastern slopes are separated by the distance of a mile or less from the western edge of the Green Mountain plateau. Westward it joins with Woodlawn Mountain in Danby and Pawlet.

North of Dorset Mountain the main valley lying between the Taconic range on the west and the plateau on the east is wide and it broadens gradually northward until it merges with the Champlain lowland at the latitude of Brandon. But north of Dorset Mountain the surface of the main valley is broken by intermediate ridges, which have been frequently mentioned in preceding pages. South of the mountain the main valley as it extends north from Manchester makes a deep embayment in the Taconic range along the West Branch of the Batten Kill. The surface of the valley south of Dorset Mountain is not broken by any ridges like those north of it and presents only minor irregularities, such as characterize the valley throughout its extent.

Dorset Mountain, besides presenting an interesting spectacle, gives the critical student an impression of holding some special significance in the geology of the region.

The higher portions of Dorset Mountain are composed of schistose rocks much like those which make up the Taconic range everywhere. Around the slopes of the mountain on the north, east and south is a fringe of marble. The schist of the mountain has been discussed in different accounts of the region as lying normally above the marble and the latter has been described as exposed everywhere that it now occurs around the slopes of the mountain, in the gulleys that dissect it and in the valleys roundabout by the erosion of a covering of schist like that which now forms the summit of the mountain.

The floor of the valley east of the mountain is very irregular and the surface rock belongs to the formation of interbedded dolomite and quartzite of the Cambrian series. These rocks extend variable distances up the east slope of the Dorset Mountain mass. Below the summits known as Netop Mountain, Dorset Hill and Green Peak the topography offers strong suggestion of a north-south fault zone and a road along the mountain side below these eminences traverses a sloping bench whose surface in the higher western portion is formed of marble with associated dolomite and in the eastern portion is made up of the dolomitic rocks of the Cambrian. At the latitude of North Dorset the road just mentioned turns abruptly east a little way south of what appears to be an east-west fracture along which the rocks that form the bench have been "dropped" against the northeastern part of the Dorset Peak mass.

On the east of Green Peak there is a vertical repetition of the marble which suggests displacements and a tier-like arrangement of the marble may also be noted west of Owls Head, and also north and northeast of Dorset Peak. Contacts of marble and schist were not found and definite indications that the marble passes beneath the schist seem to be lacking, so far as the writer's observations have gone.

The Freedley quarry at Dorset Hill is one of several openings along the same general contour on the east side of Dorset Mountain. The older openings, now abandoned, lie south of the Freedley quarry. Above the old quarries are steep ledges of schist from which have tumbled huge bowlders, each weighing many tons, which lie scattered about on the rather steep slope at the bases of these ledges. Although careful search was made, no contact of marble and schist was found. The marble at Freedley's and at the other quarries south of it usually lies nearly flat, or has westerly dip, and from this structure would be interpreted as passing beneath the schist which caps Dorset Hill; but it seems possible to interpret the relation between schist and marble in another way, in spite of the suggestion giving by the westerly dip of the marble.

The floor of the valley along the West Branch of the Batten Kill, south of the Dorset Mountain mass, shows numerous outcrops of marble or marbly limestone both to the north and south of the road from South Dorset to East Rupert and Pawlet, but the commercial marble occurs around South Dorset not far from the western margin of the interbedded rocks of the Cambrian that form the surface of the main valley and the calcareous rocks west of South Dorset, although they probably belong to the marble formation, are less altered than are the rocks near South Dorset. The sequence from east to west in these rocks is much like that shown in Brandon township.

Outcrops of calcareous rocks occur on the lower slopes of the hills that form the northward extension of the Bear Mountain mass, but these give place farther up slope to the phyllite and schist characteristic of the Taconic range. Patches of calcareous rock of indeterminable dimensions are intermingled with schist about a mile and a half northeast of East Rupert along the road that runs west of Dorset Mountain from East Rupert to Danby Four Corners. The rock is somewhat marbly and carries many patches of gray-weathering dolomite. It strongly resembles the marbly rocks found north of the Sudbury hills. It apparently occurs as a detached area surrounded by schist, although it may possibly join at the present hard rock surface with similar rock to the east of East Rupert along the approach to Kirby Hollow.

Around East Rupert and on the hill slopes south of Dorset village there are no contacts to show that the calcareous rock passes beneath the schist formation. While the drift hides contacts, the impression gained from the manner in which the calcareous rock gives place to schist is that the calcareous rock lies on the schist. The apparent absence of the calcareous rock northwest of East Rupert, except for small patches in the southern part of Pawlet township which have been described, seems to have the same meaning, namely, that the position of the schist is beneath the other rock and that the latter has been eroded from the schist northwest of East Rupert. The schist, in fact, outcrops close by the road in many places between East Rupert and Pawlet. It seems that if the schist were superior to the marble formation, the latter should have been exposed and be now visible in more places than it is along this valley.

Marbly limestone occurs on the southern slopes of the spur that bounds Dorset Hollow on the west, but elsewhere in Dorset Hollow calcareous rock was not found, except in a few outcrops on the northern slope of the Owls Head spur and in an obscure and isolated "quarry" near the foot of the trail that leads from the northern end of Dorset Hollow to the summit of Dorset Peak. The slopes of Dorset Hollow are very heavily drift covered. The drift may conceal the limestone in Dorset Hollow.

The calcareous rocks northwest of Dorset village along the surface of the valley and on the slopes adjacent show no regularity of structure, but dip in all directions, and nowhere within the circumscribing schist border of the valley around Dorset, except as schist is intermingled with the limestone around East Rupert have any outcrops of schist been found. This relation has been interpreted to mean that the calcareous rock dips beneath the schist at the border and that the schist has been eroded from the limestone of the valley, but the relations seem to admit of an alternative interpretation which is favored by the field relations that have been mentioned.

Concerning the terrigenous rocks of Dorset township as a whole it may simply be noted that they possess the general characters that have been described for the terrigenous rocks in the Taconic range from Sudbury southward and seem to show no distinctive variations.

Rupert Township.

(Pawlet and Equinox topographic sheets.)

General description. Rupert lies west of Dorset and between Pawlet on the north and Sandgate on the south. The rocks were examined only along the valley of the Mettawee and the adjacent slopes in the northeastern part of the township, and in the hollows bounding Shatterack Mountain in the southwestern part.

Except for a patch of altered limestone belonging to a small area that lies chiefly in the southern part of Pawlet and which has been described, the rocks of Rupert on the hills and in the hollows within the areas examined are schists and related rocks like those of the Taconic range in general. In the hollows, so far as seen, erosion has exposed no calcareous rock passing beneath the schist formation.

Manchester and Sandgate.

(Equinox topographic sheet.)

Location. Manchester lies south of Dorset, between Sandgate on the west and Winhall on the east. It is bounded on the south by Sunderland.

General description. A part of the western edge of the Green Mountain plateau crosses the southeastern portion of the township; Equinox Mountain with the highest peak of the Taconic range occupies the western portion, between the two is the Vermont valley.

The western slope of the plateau is formed of quartzite. West of the quartzite is a broad band of dolomitic rocks which make up most of the floor of the valley in Manchester. West of the dolomite series the outcropping rock on the piedmont slopes and in the foothills of Equinox Mountain and over a part of the western side of the valley is usually marble so that there appears to be a band of marble extending along the western side of the valley, joining at the north with the marble in the southern part of Dorset.

The marble reaches different altitudes on the eastern slope of Equinox Mountain. At the northern end of the mountain, between it and the mass of Bear Mountain is a col through which passes the road from Manchester to Beartown in Sandgate township. Calcareous rock belonging to the marble formation outcrops in this saddle at the 2,500 feet contour and was followed for a third of a mile along the trail that leads from the Beartown road to the summit of Equinox. Contact between marble and schist was not seen.

Patches of calcareous rock, apparently also belonging to the marble formation, were seen south and west of Beartown village, but the extent of the marble in the hollow around Beartown is very uncertain.

A conspicuous ledge of sheared marbly limestone southwest of Manchester village forms what is locally known as Table Rock. The ledge has a precipitous scarp on the southwest and is separated by a deep ravine, known as Cook Hollow, from a wall of schist which makes the west side of the hollow. The sides of this ravine are much steeper than the topographic map shows. The general relations offer suggestion that marble once lay against the schist along a plane of fracture.

North of Table Rock the ascent from marble to schist on the eastern side of Equinox Mountain is often steep and sometimes almost precipitous and the topography seems again to suggest the existence of old fault planes along which there has been differential movement between the marble and the schist. It seems likely that the youthful topography of this part of the region gave numerous fault line scarps where now are softened slopes of the schist formation.

The patches of calcareous rock found west of the main valley in the hollow around Beartown appear to be detached areas much like those found farther north within the range. In the southwestern part of Manchester a road from Sunderland village ascends the eastern slope of the range and crosses it to Sandgate village. Along this road in Sandgate township are detached areas of rock, probably belonging to the marble formation, which are separated at the present surface by schist. These various detached areas of limestone or marble have been explained as exposures due to erosion of a covering of schist, but examination in the field has not revealed contacts on account of the ubiquitous surface covering.

Considerations involving displacement between marble and schist on the east side of Equinox and flexure and displacement within the range seemed to the writer ample for the explanation of the occurrence of the marble in its present field relations around Equinox Mountain.

Arlington and Shaftsbury.

(Equinox topographic sheet.)

Location. Arlington lies south of Sandgate and east of Sunderland. It is bounded on the south by Shaftsbury.

General description. The eastern and southern slopes of Red Mountain northwest of Arlington village show well-defined scarps. The piedmont slopes east of the mountain give occasional outcrops of marble through the drift.

West of Arlington village the Batten Kill cuts through the range. North and south of the stream, west of the village, are frequent ledges of calcareous rocks. They are exposed chiefly close to the river and the hill slopes on each side of the stream are covered with drift. The calcareous rocks along the river in its westward course extend to a meridian about one-third of a mile west of West Arlington village and give place to schist.

In the narrow portion of the valley of the Batten Kill just west of Arlington village the actual breadth of outcrop of the calcareous rock is narrow. East of West Arlington village outcrops of such rocks occur on the piedmont slopes southwest of Red Mountain, but the actual extent of the calcareous rock is not certain because of the drift. North of West Arlington schist outcrops in numerous ledges close to the bank of Green River on contours lower than those occupied by limestone in the general vicinity. The structure of the limestone is irregular and again the field relations suggest that the schist has an inferior position.

West and southwest of Arlington village marble occurs on the west side of the Vermont valley at the base of the eastern slope of The Ball and gives place up the slope to schist. Contact was not seen. Prominent scarp topography on the east side of The Ball is lacking.

South of The Ball is Dry Brook hollow. Where this hollow opens into the main valley there occur near the junction of the piedmont road with one running east from it outcrops of the mountain schist, clearly in place. These outcrops are on meridians farther east than those occupied by marble ledges farther south on the eastern slope of Spruce Peak. The erosion which produced Dry Brook hollow apparently has not exposed marble which it seemingly should have done if the marble passes beneath the schist. In the hollow of Tanner Brook, southwest of Manchester village, schist was also found on meridians east of and on contours lower than those occupied by marble.

Northwest of Shaftsbury village the eastern slope of West Mountain gives somewhat modified scarps in the schist and the schist descends to contours so low that in places the relations give the impression that the schist forms the rock beneath the drift at places along the west side of the valley in this town.

In Arlington and Shaftsbury, as in Manchester and Dorset, topography and field relations are not out of harmony with the idea that the marble and schist have their respective positions of account of displacements by which the marble has come to have a position that gives the impression that it passes beneath the schist.

GENERAL SUMMARY.

It has doubtless become apparent to those who have read the foregoing pages that a question has been raised as to the stratigraphic position which has been assigned to the "Berkshire Schist" formation of the Taconic range, in its relation to associated calcareous rocks of probable Ordovician age. Proof has not been given that the interpretation of the age relations of the schist as described by other students is wrong. Suggestions have, however, been offered on the basis of study of field relations that these relations at many places are rather definitely in harmony with another interpretation and at other places are not apparently devoid of support to such interpretation.

At the risk of some repetition the field relations which have been emphasized in the preceding pages of this paper and in other papers will be briefly reviewed.

In the northern part of the Taconic range and in the southern portion of the Champlain lowland, certain terrigenous rocks which have their counterparts or closely similar types practically throughout the Taconic region and which consist of graywacke quartzite, or rather pure compact, quartzite, and various schists and phyllites, seem to occupy a position inferior to various calcareous rocks. In Benson, Orwell, Sudbury, Whiting and Cornwall the calcareous rocks just mentioned carry fossils and may be satisfactorily correlated with Lower and Middle Ordovician rocks of the lake region.

The fossiliferous limestones of eastern Orwell township join at the surface with marbly rocks at the northern end of the Taconic range in Sudbury and these in turn with similar altered limestones or marbles in Brandon township. The greatly altered marbly rocks of Sudbury and Brandon are for the most part of uncertain age, as fossils are generally absent in them, but from such fossils as have been found and from surface relations and to some extent on account of certain lithological features they are regarded as the eastward representatives of rocks of the lake region.

The marbles and other altered limestones found in Brandon extend with some interruption northward along the eastern portion of the Champlain lowland and southward along the Vermont valley. In Brandon and the areas to the north and south the marbly rocks are everywhere more or less extensively involved with dolomitic rocks, regarded as of Lower Cambrian age.

East of the Vermont valley and the Champlain lowland the dolomitic rocks which form a broad band along the eastern portion of the lowland and which make up most of the hard rock surface of the Vermont valley give place to terrigenous rocks which form the foothills and western slopes of the Green Mountain plateau and, in some cases, a part of the valley floor and that of the lowland. These terrigenous rocks are quartzites, or quartzites and schist, and make up what has been called the "Vermont Formation," regarded as of Lower Cambrian age.

East of Brandon and Rutland and elsewhere along the edge of the plateau the terrigenous rocks considered as a whole give an assemblage, which, in spite of differences in proportions of certain kinds of rocks and variations of one kind or other, is very much like that afforded by the rocks of the Sudbury hills and other parts of the Taconic range. The resemblance is indeed so strong that it was early suspected that these various rocks might belong to the same general formation.

In view of the apparently inferior position which the terrigenous rocks in Sudbury have to the calcareous rocks and from the field relations between those two kinds of rocks farther north in Whiting and Cornwall and also in the western part of Brandon, it seemed reasonable to infer that the terrigenous rocks in Sudbury are joined to those in the western edge of the plateau beneath the intervening marbles and dolomites of the valley. This distinctly does not mean necessarily that the terrigenous rocks now forming the edge of the plateau have at the present time their primary relation to those which underlie the valley rocks, for it is clear that the plateau rocks have been disturbed probably by normal faulting and probably also by thrusting which occurred prior to normal faulting. Northwest, west and southwest of Rutland parts of the terrigenous formation that lies beneath the calcareous rocks of the valley have been thrust into the latter and on account of later normal faulting the original thrust relations have been preserved. The terrigenous rocks now form the intermediate ridges in the valley around Rutland which have been described.

The reader should perhaps be reminded at this point that not all of the terrigenous rock making up the intermediate ridges just mentioned is regarded by some students as belonging to a formation lying normally beneath the valley limestones and dolomites, but that on the contrary the schist is put above the marble and correlated with the schist of the Taconic range, which is also considered to lie above the marble and to be of Ordovician age.

The field evidence of displacement between the rocks of the plateau and those of the Vermont valley appears to be decisive. In the foregoing pages numerous indications of apparently normal fault displacement between the valley rocks and those of the Taconic range have been discussed. At some places the schist of the range descends to contours below those occupied by marble and in some of these cases and at other places the schist outcrops in the western floor of the valley east of the western margin of the marble formation. Scarps in the schist formation along the east slopes of the range are frequent. Topography and to some extent geological relations between schist and marble seem to bear out the idea of displacement between the rocks of the range and those of the valley. On account of recession of scarps by erosion some of them are now much less prominent than they seemingly must once have been. Talus from the scarps or drift conceals contacts between marble and schist.

North of the West Rutland valley, which it will be recalled is a subordinate one in the main Vermont valley, schist apparently occupies both the upthrow and the downthrow sides of normal fault displacements. In the eastern part of Sudbury the faulting may be followed in some places between masses of schist and in others between schist and marble. At Dorset Mountain and along the west side of the valley southward the marble occurs often at different levels and often seems to have a faulted relation to the schist similar to that shown in the eastern part of Sudbury. Outcrops of schist in the floor of the valley at the bases of steep eastern slopes of the range and frequently to the east of the western margin of the marble formation in the immediate vicinity as found north and south of Dorset Mountain, duplicate again the relations which are to be found in Sudbury. Such outcrops of schist seems to be due to erosion of overlying marble. The schist would probably be visible at other places along the west side of the Vermont valley if the surface covering were removed.

If the Vermont valley is interpreted as a great downthrow region between the Green Mountain plateau and the Taconic range one may by aid of the imagination restore in some degree the relations which obtained prior to the differential movements that produced the structural outlines of the valley. In imagination then the various rocks making up the floor of the valley may be thought of as elevated until the schist and quartzite which presumably underlie the dolomites and marbles are brought to the level which the terrigenous rocks east and west of the valley had prior to displacement of the valley rocks. This level would be somewhat higher than the present surfaces of plateau and range because these must have suffered some erosion. After such an imaginary elevation has been made the marble that now in general forms a belt or band along the west side of the Vermont valley is brought to a position in which one may further view it as part of a more extensive mass of similar calcareous rock lying above the schist formation of the Taconic range. The present distribution of the marble along the west side of the valley and its apparent relation to the schist of the range would then be circumstances resulting from displacement and the marble would be thought of as a dismembered part of a mass of similar rock that has now largely disappeared from the schist of the range.

The westward extension of the marble through South Dorset and Dorset villages in the valley south of Dorset Mountain and the fringe of marble on the north side of the mountain, as well as other present extensions of the marble from the valley into the range, could be explained as due to displacement, by which the marble was "dropped." On this view it is not difficult to understand why the marble in its extensions into the range at different levels gives place to schist westward along the present surface with no indications that the marble dips beneath the schist, and also why marble does not appear in the deep hollows of the range. Where marble, or calcareous rock apparently to be correlated with it, does occur in detached areas within the range it may be regarded as preserved through downfaulting, or possibly as the result of having been involved in thrusting.

According to the views just presented the apparent relations which exist now between schist and calcareous rocks in Sudbury and the towns north of it formerly prevailed over the Taconic range. It further becomes possible to understand why schist does not occur generally over the Champlain lowland above marbly rocks that are seemingly broadly to be correlated with the marble of the Vermont valley and the calcareous rocks of Sudbury.

If, as seems not unlikely, there once lay over the schist of the Taconic range a vast mass of calcareous rock which has largely been removed, it is probable that the erosion of this rock was accomplished prior to the dissection which the present surface shows. Some of the hollows within the range may have once contained some calcareous rock, but it is not necessary to assume that they did and that they were formed by the erosion of such rock.

As has already been discussed there are topographic indications of faulting in various parts of the Taconic range, west of its eastern borders, but the apparent faults in most cases extend through or between terrigenous rocks at the present surface and the fact of displacement is not so readily shown as when marble or limestone rest against schist along a fault plane as is the case in places at the northern end of the range. The probability of the existence of normal faults at many places within the range is strong.

The terrigenous rocks of the Taconic region and the rocks that presumably once lay over them probably also suffered ancient displacements from thrusting and it is possible to imagine that relations like those shown by the marbles and schist in the Vermont valley near Rutland may once have been present within the range and that on account of heavy erosion such relations have been destroyed. Ancient peneplanation and later dissection have operated to obscure thrust relations among the rocks, if such occurred.

The considerations so far offered have been in the direction, so to speak, of restoring an extensive mass of calcareous rock on the schist of the Taconic range and of explaining the distribution of the marble along the west side of the Vermont valley as the result of faulting. It is not clear how much schist should be restored to the present surface of the range to give the surface on which the marble formation is supposed to have lain.

The normal faults that are regarded as having produced the structural outlines of the Vermont valley did not everywhere involve the same amount of displacement and so we see the marble occupying different levels. It also has different levels on account of unequal erosion.

GEOLOGY OF A SMALL TRACT IN SOUTH CENTRAL VERMONT.

George D. Hubbard,

Oberlin College.

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INTRODUCTION.

This piece of geologic work has been done mainly during the summer of 1924. It has been for nearly twenty years the custom for the Department of Geology and Geography of Oberlin College, located at Oberlin, Ohio, to offer a field course in geology as an organic part of the Oberlin summer session. The students registering for this course have numbered each year from six to twelve, and the work has been carried on three summers in southern Vermont.

The class goes into camp in some favorable locality for a seven-weeks' stay and works out in all directions a reasonable day's tramp from the base, all students returning each night. A report on the geology of the area is prepared by each student to complete and round out the study and gain the college credit for the course. In 1924 the class numbered nine and three colleges were represented, Otterbein and Oberlin in Ohio and DePauw in Indiana.

This place was chosen for the work in spite of its distance from Ohio, because it was not already worked and because it had a wide range of problems within a small compass. There are found in the area a considerable variety of metamorphic rocks, derived from Paleozoic sediments; several bodies of intruded, igneous rocks representing a similar range in time, and in variety of rocks, there has been much erosion, heavy glaciation and more subsequent erosion bringing the topography into its present state.

Our work consisted in making enough topographic map to learn the methods employed, in mapping the geology on the United States Geological Survey topographic map as far as we went, in working out the structure of the rocks, in mapping the glacial features so far as possible, in interpreting the succession of events comprised in the geologic history of the region, and in the gathering of data on the geologic resources available.

Location and Area.—The area covered is about six and a half miles north and south, and ten miles east and west, thus containing about 65 square miles or rather more than one-fourth of a 15-minute quadrangle. The northern boundary is the parallel of 42° 50′, the southern is about 42° 44′, or more exactly the Vermont-Massachusetts state boundary. The west line is the 73° meridian and the east is about 72° 47′, or the Whitingham-Halifax township line.

Geologically the area extends transverse to the structures in the metamorphics of southern New England and for this reason is very fortunately situated to disclose these structures.

Our area lies in south central Vermont, about one-third in Bennington and the rest in Windham County. Readsboro, Whitingham and Jacksonville are in the area, the first and second named villages are in townships by the same names. The town of Whitingham has recently been receiving notoriety because of the construction of a large power dam on the Deerfield River.

This river flows entirely across the area from north to south and the Wilmington and Hoosac Tunnel Railroad follows it the whole distance. Because of the construction of the huge power dam the railroad had to be moved up the valley walls much of the distance across the area. This and other items connected with the operations of the Power Construction Company, necessitated making many fresh cuts in the rocks, which greatly aided the geologic work.

Physiographically the area is a part of the New England Province and while it lies almost on the southern borders of the Green Mountains, it does not extend into them at all. It is a portion of the maturely dissected, glaciated upland, a partial peneplain with monadnocks.

Outline of Geology. There is little doubt that the first event recorded in the exposed rocks of this area was the making of limestone in the sea which covered the region. Then came clays and sands rarely well sorted, but varying from very sandy to very clayey in composition. Hundreds of feet of these, possibly thousands were laid, and probably other kinds as well, until what are now exposed became deeply covered.

Then came diastrophic and metamorphic processes, the former folding, mashing and uplifting the rocks, the latter carrying on changes within them until clays and shales became schists, and sands became quartzites, while the old limestones below became marbles. There is no way of knowing in our area how thick the marble is, nor what underlies it, but evidence from other related localities makes it clear that we may expect much schist and more calcareous rocks below the lowest in our section.

The foldings are very complex, the metamorphism is quite complete, the uplift has been oft repeated. And after some metamorphism and probably after most of the folding, came repeated but meager intrusion of igneous rock. At least four periods of intrusion are recognized and four kinds of rock have been left in the metamorphics. Some of the igneous rocks are responsible for a little metamorphism along their contacts.

Outline of Topographic History.—Long before the events listed in the above paragraph were completed, erosion must have begun. Streams attacked the surface of all forms exposed to them. Weathering and erosion have made enormous inroads on the rocks of this region. Thousands of feet of material have been removed and the present forms carved from rocks uncovered by the earlier erosion.

The hills carry, in the outlines, the evidence of advanced maturity, but more careful scrutiny also shows that there are still preserved records of several cycles of erosion. The upper slopes are the more mature. Monadnocks rise above a general level reached by large numbers of the hills. This general level, higher in the northern and western part, represents the peneplain produced by a rather complete ancient cycle, the monadnocks, residual hills not even then removed. The remnants of this old erosion surface are probably the most mature slopes. Below these have been carved many wide valleys with slopes steeper, but yet mature, and on a level a few hundred feet below the upper peneplain, has been formed a less complete one, with much larger residual masses rising above. The cycle of erosion producing this second peneplain was interrupted and a third cycle was begun, but this latter only reached submaturity before it was itself interrupted by the great continental glacier which spread over all of Vermont.

It is probable that the ice sheet came at least twice and that it was gone long enough between the two advances to allow the streams time to do considerable interglacial carving in the drift-filling of old valleys, and some even in the rocks, where they had opportunity. Ice deposition and ice carving added many details to the topography.

When the ice sheet had finally melted away the last time the streams started in again, and while the time has been quite limited they have attained rather notable results in some places. Streams have carved out the drift and carried it away from many old valleys, opening them up again something as they were before the ice came. In many places they have encountered rock and have been held up thereby. Some valleys are narrow and rocky where the postglacial streams did not find the wide preglacial courses, other streams have worked all these thousands of postglacial years and have not yet encountered rock anywhere nor have they nearly emptied their old valleys of drift.

Thus glacial erosion and deposition and postglacial stream work have put the ornament and detail upon the preglacial framework made by long erosion on complex rock structures.

TOPOGRAPHY.

Relief and Pattern.—The highest land in the area is about four miles north of Readsboro, where a summit attains the altitude of 3,024 feet above sea-level. The lowest place is where the main stream, Deerfield, leaves the area over the Massachusetts boundary. The stream bed here is 1,040 feet high. Thus we have a total relief of almost 2,000 feet. East Branch of North River, flowing southeast from Jacksonville, attains a lower depth before it leaves the Wilmington quadrangle,[1] but within the area studied it has not cut below 1,200 feet.

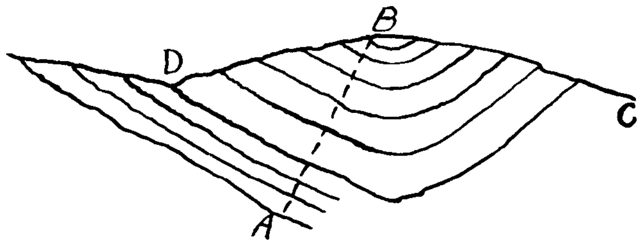

FIGURE 2. Structure section across the Deerfield valley east of camp and across the hill (B) through which the tunnel goes (line A-B on map). Strata of Readsboro dip very uniformly eastward across valley. Line A to B on section measures the thickness of Readsboro. Horizontal and vertical scale 1 inch = 1 mile.

While the highest land we have is over 3,000 feet, probably less than two square miles of area surpasses 2,500 feet, and this area is scattered in three small patches along the western side, one on the northern border of the territory, and one over the larger summit of the hill attaining the maximum.

Between 2,000 and 2,500 feet altitude there are about three square miles east of the river scattered in nine small patches, one of which, south of Whitingham is called Jilson Hill and contains nearly two square miles. On the west side are four areas, one a mile north of Readsboro of a few acres, one surrounding the summit peak of over three square miles, one on Lord Peak west of Readsboro of about 40 acres and a straggling irregular area along the western side, in places more than a mile wide and occupying seven to eight square miles. In all there are only about 14 square miles between 2,000 and 2,500 feet altitude.

The land below 2,000 and above 1,500 is by far the most abundant. A large area lies along the Deerfield and connected with it another bordering West Branch Deerfield River and extending over the hills southward beyond Lord Peak. East of the river all save the summits mentioned and two small areas on East Branch North River and on Deerfield, both below 1,500 feet, belong in the 1,500-2,000 feet area. This range of altitude thus comprises about 40 square miles.

[1] The reader will do well to have before him the Wilmington, Vt., quadrangle of the U. S. Geol. Surv.

The areas below 1,500 are nearly all along Deerfield and submerged above the big dam. A small strip follows up West Branch for two miles and a similar area lies around Jacksonville and down stream therefrom. All land below 1,500 feet probably does not make up more than 8 or 9 square miles.

Above 2,500 = 2 square miles.
2,500-2,000 = 14 square miles.
2,000-1,500 = 40 square miles.
Below 1,500 = 9 square miles.

Probably three-quarters of the whole area is between 2,250 and 1,600 and almost all the gentler slopes are within these limits. Many slopes above 2,250 are steeper and most of those below 1,600 are steeper except those actually on the flood plains. But while slopes over 2,250 in altitude are steeper, no summit is an actual peak. All are rounded domes or ovals. Plate XX. No upper slopes exceed one foot in six and many are as gentle as one in ten or twelve feet. In the great 1,600-2,250 level, slopes are rarely as steep as one in twelve and often as gentle as one in 25 or 30. One can go occasionally a half mile or more in a straight line without a change of level of 20 feet.

The lower slopes, below 1,600 feet, are steepest of all. Some are difficult to climb: 400 feet in 1,400 or even 1,200 are found and slopes of one in two are common for short distances of 200 to 300 feet. This steepness is not notable youth while mingled with some gentler slopes, but it represents vastly younger topography than the gentler slopes above. It must be considered very significant that the steeper slopes are in the lower levels, and that so large a percentage of the area is within so small a vertical range, and neither near the top nor near the bottoms of the valleys.

Drainage.—Drainage is essentially all above ground, although a few sink holes in two or three areas no doubt assist a little. The drainage pattern is a modified dendritic. The Deerfield is easily the master stream with a very meandering course across the area. About one-fourth of the territory is drained eastward to the Connecticut by East Branch of North River and its small tributaries. The chief branch of Deerfield is West Branch, nearly all of which is within the area. Brooks, runs, creeks, and rivulets in abundance remove all the water readily, except that contained in a few small lakes and marshy tracts to be mentioned in another paragraph.

It is obvious that in the main the present topography consists of preglacial stream-made forms mantled with drift, therefore, the streams wherever possible are in preglacial valleys. Preglacial drainage was certainly southward. Old valleys uniformly converge in that direction. The only notable exception to this statement is in the area about Whitingham occupied by Sadawga Pond and its feeders and outlet. At present this valley drains largely northward and its stream enters Deerfield headed upstream. No preglacial tributary could have joined the river at this place without coming in headed upstream for at least a mile of its lower course.

For a discussion of drainage modifications, read the glacial history on later pages.

Lakes are few and in almost every case partly artificial. Sadawga Pond was the largest natural reservoir. It was long ago enlarged a little by a dam at the north end, and now within the last year or so, this dam has been enlarged and the pond extended to conserve more water above the big dam for power purposes. The pond now covers over half a square mile and has a length of more than a mile. Plate XVIII. Its outlet is down a steep rocky incline for a half mile to the present Whitingham reservoir in Deerfield valley. Its borders are everywhere of drift and its shorelines lie on gentle slopes. Its area could be easily increased 50 percent by raising the dam 10-12 feet more. There is considerable peat in this pond, but owing to its repeated increase in size none is now above water. It has a small so-called floating island. This is not an island free to migrate over the lake, but to rise and fall where it is with the water. It consists of roots, stems and other vegetation (with some highly organic soil), which is attached to the bottom by long stems so it cannot leave its moorings, but can float and rise and fall as lake-level changes.

The second in point of size is Howe Pond in the far western part. This too is natural, but has been enlarged by a small dam across the east side. It is extensively used for boating, fishing, cottaging, and its waters are piped to Readsboro as a village water supply. This pond is nearly a mile long, but is somewhat narrower than Sadawga.

In the southeastern part of the area within three-fourths mile of the state line is a more or less circular pond 1,200 to 1,500 feet across, surrounded by drift and apparently wholly a glacial kettle. It drains by a small brook to East Branch.

Similarly, two smaller lakes, wholly kettles lie about two miles north of Jacksonville. One is entirely surrounded by drift, the other is simply a wider place in the stream where the water is retarded by a small obstruction.

Two miles northwest from Jacksonville is a small remnant of a larger pond now in a marshy, peaty area and well called Two-way Pond, for water leaves it at both northwest and southeast ends, one portion headed for Deerfield, the other for the Connecticut.

A pond one-fourth by one-half mile in dimensions is held up in a hanging valley above Jacksonville by an artificial dam. There seems to have been some pond here, and more swamp due to glacial interference with the drainage, but man has added to the

PLATE XVIII.

Sadawga Pond from the south with a part of Whitingham village on opposite shore. Swampy land in foreground. Rounded residual hills in far distance.

obstruction and made of it a quite serviceable mill pond. Apparently no use is made of its waters at present.

Many years ago a mill pond was caused in Readsboro by erecting a large wooden dam across the stream. The water was used for power until recently. Similarly two dams have been built and used in the West Branch, one near town and the other near Readsboro Falls. Neither had any natural basis of pond, but both are at excellent places to build dams.

In 1922-23 a very large earth dam was constructed across the Deerfield at a place about three miles above Readsboro and less than one mile below Davis Bridge and at the present Whitingham stop on the railroad. This dam has a huge concrete spillway underneath, which receives its water through a large funnel of concrete before the dam is quite full. The dam sets the water back in the river about 10 miles and destroys the usefulness of of the plant at Mountain Mills, two miles from Wilmington. It drowns the mouths of all tributaries in this distance and makes a reservoir, with a depth of water almost 200 feet in its deepest part, and an area of about six square miles. Lying as it does between the rather steep slopes of the valley it makes a very beautiful reservoir, which may serve many uses beside the turning of the three power wheels located a few miles down valley. The water is led nearly southward through a tunnel two and one-fourth miles long to a place where it intercepts the river, and the water is returned to the stream after descending about 400 feet in penstocks and passing over powerful waterwheels.

Glaciation.—The work of the glaciers is the most obvious in the region. The whole area was covered by the ice sheet more than once. Old buried drift is found in several places as evidence of at least one early ice invasion. The later fresh drift abounds everywhere except on occasional nearly bare rock surfaces, testifying to the work of the Wisconsin glacier.

When the ice came the region had already passed through its several cycles of erosion, with the exception of the one called postglacial. Hence the topography was mature to advanced mature and in places old. The drift mantles all these old erosion forms, but they are discerned through the cover. It is from a study of these partly concealed forms described above that we know what the country looked like when the ice came.

Postglacial Erosion.—We saw a youthful cycle, which had been started on advanced mature topography, interrupted repeatedly by the ice. Each time the ice melted away the streams resumed their task. Interglacial stages were as long as postglacial time has been, hence each interglacial erosion cycle may have advanced as far as the present postglacial cycle has. And after its meager start each such cycle was again interrupted. Finally the ice melted away for the last time and the present cycle began. Little progress has as yet been made. Many drift forms and even glacial lakes still persist undisturbed by stream work. Streams have not nearly cleared the drift out of their old valleys. In places they have cut through the drift to rock, but even with that accomplished, great quantities of drift still partly obstruct valleys. Little or no new soil has been made by rock decay. The drift lies on fresh rock just as when first deposited.

Yet a start has been made and as time goes on the re-excavation of the earlier valleys will be accomplished and the deepening of rock valleys to base-level will proceed. The interrupted cycle will thus be taken up again and pushed on to completion. Post-glacial erosion now just begun will, if time allows, produce just as complete a cycle as either of the erosion periods that passed in preglacial time.

DESCRIPTIVE GEOLOGY.

General.—The area under consideration has a larger variety of rocks than is generally supposed, but not as wide a range as some areas of similar size.. Metamorphic rocks greatly predominate and these are very largely of sedimentary origin. The metamorphics are marbles and schists. The former were made from somewhat impure limestones and now contain a considerable number of accidental minerals, graphite, pyrite, quartz, tremolite, several micas and other minerals. Among the schists, quartz-mica types make up almost the whole list, but the proportions of the two minerals vary much. Some are so siliceous as to be almost quartzites, others so micaceous as to be essentially phyllites. The schists also vary considerably in their accessory minerals. Albite occurs in some, garnets and tourmaline vie with each other for position; magnetite, pyrite and various amphiboles are common. Several different micas in varying proportions add to the complexity. Schists differ much in color. Gray predominates in the central part of the area, blue is common in the western third and green to greenish black in the eastern portion. Some of the schists are brilliant and sparkling with their fresh micas. Some are dull, even when fresh.

The schists differ much even in short distances in their physical properties. Some split very nicely for economic uses, others seem to have no cleavage. Some are strong and resistant, some powder up and crumble readily under the hammers of weather and decay.

The igneous are all younger than the metamorphics. They occur in considerable range of type and condition. There are very basic rocks and dikes of almost pure quartz. All igneous rocks are in dikes and the range in size runs from the merest stringers to bodies 200 to 300 feet across, with occasional occurrences nearly twice as thick. No sills or larger bodies are known. The dikes are always in the metamorphics and in all types of metamorphics, they are scattered pretty freely all over our area.

Intersections of the several kinds are known in sufficient variety to make the order of intrusion of the several types perfectly clear.

All the intrusions were made when there was a thick cover over the rocks now at the surface, so that the effect of intrusion and the types of dike crystallization are such as occur under pressure and thick cover. This may be interpreted to mean that the intrusions preceded the earliest cycle of erosion whose records are still extant in the region, which may put most of the igneous activity into the Paleozoic age. No intrusions found were made so recently that they came anywhere nearly to the surface, that is, what was the surface when the intrusion occurred.

Sedimentary rocks are all very recent and as yet wholly unconsolidated. They belong to the Pleistocene and the Recent and are all glacial, glacio-fluvial or purely alluvial deposits, except that of course a few lacustrine deposits lie below the waters of present lakes, and in the beds of extinct lakes. These all would also be Pleistocene and Recent. The sedimentaries lie unconformably everywhere over the ancient crystalline metamorphic and igneous rocks.

METAMORPHIC ROCKS.

Sherman Marble.—The oldest rocks are the metamorphics, and the oldest metamorphic is the marble to which we have given the name of the town where it is most extensively exposed and worked—Sherman, on the Hoosac Tunnel and Wilmington Railroad.

Marble was found in about a score of places all in the southern central part of the area studied. Nearest to Readsboro of all were the meager finds on the nose of the spur in the loop of the river. This would be just east and southeast of town on the hills above the old box factory now being removed. Loose fragments of the rock were first found, then larger boulders and a few pieces possibly in place. The marble seems never to withstand weathering by solution more than a few rods from the outcrops where known crops occur, hence we infer that where only loose pieces were found the ledges must be near. Farther up the slope eastward on this spur about a half mile from the village end of the spur, and east of the large schist ridges crossing the spur from north to south are several pieces of float and a few ledges of marble. These occurrences are so placed as to make it clear that some of them are actually in place, and all of them very near their sources. They continue entirely across the ridge from north to south. Those on the east side of the strip dip eastward, those on the west dip westward. Across the river northward from these occurrences are the outcrops first seen in our area. They were right near camp on the slopes around and above the Bailey home and on pasture land belonging to the

Whitneys. Zigzag lines of marble (Plate XIX-A) outcrop here constituting at least three strong layers easily traceable in the pasture, and between them are weaker layers that weather down and cannot be seen. These three stronger layers converge northward rapidly, the inner pair meeting in the leveler area and the middle pair meeting just at the edge of the steeper slopes, while the outer pair run under cover of waste from the overlying rocks and disappear before they meet.

The outer layers can be traced up the hills northward to altitudes of 100 to 150 feet, at least, above the outcrops in the pasture. The lines of outcrops can also be traced down to the private road in one case and nearly to it west of Bailey's barn in another case.

The outcrops on the south side of the stream and those on the north are no doubt connected below the river, but they have been cut out very completely near the stream and cannot be actually traced across. Approximately on the eastern limb of the structure, or better on the outer layer of the east side as defined above, and down slope 200 feet or so below the private drive occurs a big, cold spring with marble showing in two or three places about it. Sink holes back in the pasture suggest a connection here. Surely the spring waters come out of the marble, probably they are the same that go in at the sinks farther north.

Dale[1] describes an outcrop of graphitic, micaceous, calcite marble about one-fourth mile north of the local dam in Readsboro village. This occurrence we surmised and needed in our findings, and we searched for it carefully but did not find it. We did not know when in the field that it had ever been found. We did find, however, the formations that overlie the marble in a good anticlinal structure in this locality. The map shows Dale's find of marble and our interpretation of the succeeding beds. This is apparently in the same anticline as that near the end of the nose of land in the loop of the river, *i. e.*, the first outcrops described above.

Another notable occurrence of marble has been extensively worked at Sherman on the railroad, a little over two miles down stream from Readsboro. Railroad construction necessitated a cut of considerable extent in the marble, and a few years ago a large plant was put up to make carbide of calcium from the marble. The quarry opened shows a fine section of the marble dipping eastward into the hill. And southward for nearly one-half mile a ridge of marble can be traced, rising as a small hill in the side of the valley. So strong is the south pitch of the anticline that it goes completely under younger layers before the state line is reached.

[1] Dale, T. N., Calcite Marble and Dolomite of Eastern Vermont, U. S. G. S., Bull. 589, p. 52.

PLATE XIX-A.

Sherman marble near camp, S-25. Several bands of outcrop (strong layers) between covered intervals (weak layers).

PLATE XIX-B.

Sherman marble at S-25, near view. Lenses of mica, darker bands, and quartz cut off in center and left, by a fault.

This area of marble continues northward more than a half mile from the old carbide plant and the railroad cut. Some of the distance the marble is covered with waste, but northward under the power line it can be seen almost continuously for several hundred feet. Again on the west side of the river a few hundred feet upstream from the Sherman Bridge are small outcrops which were opened commercially long ago. Here the beds dip west and at Sherman they dip east, and the whole structure pitches northward and southward and carries the marble down out of sight at each end. The total area of marble exposed, including all that is covered with waste, is probably not much more than a mile north and south and less than 2,000 feet wide in the central part. Since the sides converge so rapidly in the pitching anticline the area is narrow and tapering at both ends.

About one mile east of this area occurs a very interesting group of marble outcrops. From the first outcrop, one mile east of Sherman, the area continues a mile east and a mile north with frequent ledges of marble. For the sake of a name this group will be called the Whitingham area. It will thus be distinguished from all others, even though the Sherman area is in Whitingham township. All marble outcrops in the area are long and narrow, trending north and south. See map. In this square mile, at least 12 patches of marble are found. In many cases the same patch shows dips in opposite directions as if it were the crest of a little fold or wrinkle. At least six wrinkles are known across the northern part of the square mile, large enough to bring marble up to the erosion surface. In the middle part as many wrinkles are known but only three seem to bring marble up, while in the southern part at least five are known, three of which bring marble out. The eastern marble patch in each of these three sections may be in the same wrinkle. Possibly the western patch in the northern section may be the same as the western in the southern section. No other connections are even probable. There must be, therefore, at least 14 wrinkles in this little area. The whole series seems to be in a larger anticlinal structure of rather short dimensions north and south, and pitching steeply at each end under younger strata.

In the north-south valley west of Sadawga Pond about three-fourths of a mile southwest of Whitingham village, marble has been quarried on the east side of the brook and burned on the west side. Dale[1] mentions and briefly describes this marble, but we did not see it owing to the condition of this valley in consequence of the Whitingham dam. Either water sets back over the place, or brush cut along the reservoir shoreline or the new road improvements conceal the place. The marble is described as coarse, abounding in phlogopite scales up to one-half inch across,

[1] Dale, T. N., Calcite Marble and Dolomite of Eastern Vermont, U. S. G. S., Bull. 589, pp. 49-50.

with graphite, quartz, and rarely actinolite. This occurrence is in line with the structures found a mile farther south and mineralogically remarkably similar. It no doubt outcrops here because brought up by a wrinkle similar to those farther south. It is put on the map in what is left blank as water area and the formations next it are omitted.

This occurrence lends more color to the suggestion later, that marble may be near or at the surface beneath the water in Sadawga Pond.

In no other part of the area is marble found. Each occurrence is in a known anticline, but many anticlines are known with no marble.

Since in all these occurrences the marble dips outward from an axis beneath other layers, since all the marble in the area is quite similar, and since the rock succession above the marble is always the same, it seems reasonable to infer that the marble is continuous beneath other rocks from one area to another. And if it underlies thus a considerale portion of the southern part of our area, we also infer that it underlies the whole area. Evidence of a continuation of its immediately overlying beds will be presented later. They are known all across the western part of the area, and our general structure is such as to lead to the belief that they go under younger rocks in the eastern part.

Marble of similar character and relations is known in several places northward beyond the Readsboro area. In previous work done in 1916 and 1920 our party found the marble areas reported by Dale[1] in Binney Brook two miles northwest from Wilmington, in the Wheeler Hill two miles west of Wilmington and south of the Deerfield, also up the hill in several places even to its summit, in Mt. Pisgah three to four miles north of Haystack Peak and again south of Haystack Pond.

With so much evidence of the continuity of the Sherman marble under most of the country, two further suggestions may be made. The first concerns Sadawga Pond area. While no marble was found anywhere around the pond, and while the beds immediately overlying the marble were not found in this area, it may be that the land is low where now stretches Sadawga Pond because the marble was reached by erosion. For comparison it would not be difficult to imagine drift so placed around the Whitingham marble area as to retain water and similarly make there a considerable lake. If marble is in the Sadawga Pond area at the surface, sink holes may be expected some day to develop and offer subterranean outlets westward for the waters of the pond unless the syncline between it and the river is too low to let the water under.

The other suggestion is of the same nature and is based on

[1]Dale, T. N., Bull. 589, U. S. G. S. (1915), pp. 47-49.

equally good evidence. It is to the effect that Howe Pond, two to three miles west of Readsboro may lie in another area in which the marble has been reached. Both north and south of the pond outcrops of the rocks immediately overlying the marble were found. Drift covers much of the rock and together with the water completely conceals the marble if it does occur here. It should be urged in support of these suggestions that the marble must be near, if not actually at the surface of the rock just below the drift in both places.

The marble is usually gray to white, coarse crystalline, granular, and does not hold together very well, but at Sherman some of it is very firm and would handle well. The friableness in other localities may be due to weathering, for we have been unable to break deeply into it in any of the occurrences except at the Sherman quarry.

Other colors than gray and white are known. Pink tints occur in the old pit across the river from Sherman. Yellow bands occur at Sherman. Pink marble in beautiful tints is found in the extreme southwestern outcrops of the Whitingham area in square e-34 and again at h-30 in the extreme northeast part. Yellow tints occur near camp at S-24, and in the large area at e-f-28-29.

In texture the marble is usually medium grained, but near the top some coarse beds appear and where the graphite is coarse the calcite crystals are generally large too. In e-f-33 an old quarry showed much coarse calcite with crystals at least an inch through. Some of this coarse material was yellow, other masses red, resembling very much flesh red feldspar. Iron is present in small amounts and probably is the cause of the color. This occurrence seems to be simply recrystallized marble. It has been opened for commercial purposes and fine exposures made.

Accessory Minerals in Sherman Marble.—The marble is rarely pure calcium carbonate even for single layers, and for short distances. Nearly every sample gives a feeble iron reaction. Dolomite is common. The formation could well be called dolomitic for many samples, all that were tested, gave a strong magnesium reaction.[1] But in some places accessory minerals make up a very considerable part of the rock.

At Sherman graphite is common, particularly in the lower layers exposed. Crystals as large as peas occur, but more frequently they are mere specks to the size of pin heads. Much of the graphite is in bunches, but some is in more or less continuous layers, making the rock gray and streaked. Samples could be

[1] In cold dilute hydrochloric acid every sample examined, and from all localities, effervesced freely at the start. After a few moments the reaction became slow and the addition of fresh acid failed to stimulate it. Yet in time every sample completely dissolved in the cold acid, except for the small residue of silica and silicates entangled in the sample. Heating at any stage in the slow process stimulated the reaction. On these results it is believed that the formation contains both calcite and dolomite. The acetic acid separation was not tried.

taken having 10 to 15 percent of graphite. Most of it is foliated or flaky, some shows a radiate pattern. Graphite is not so common higher up in the Sherman outcrops, but occurs nearly all through the rock. In other places it is also sparing. At camp, on the Whitney farm one-half mile east of Readsboro, many small crystals were seen. Across the river south the graphite is also rare, and in the Whitingham group of outcrops it is only occasionally seen. No outcrop is so thick as that at Sherman, and it seems probable that the graphite is confined largely to lower layers. Other minerals are much more common in the upper layers.

Tremolite and actinolite are abundant in most of the localities. They seem to belong much more to the upper part and to become rare downward. Some very showy specimens were collected near the upper contacts, also near the railroad at Sherman. This latter occurrence would not be near the contact. The crystals are long, prismatic, often very slender and range in color from white through delicate tints of aquamarine to green and even dark green. Some are as large as cambric needles, others can be seen only with a lens. Tremolite is usually in small bundles of crystals two to four similar in size, then two or three more lying at an angle with the first. Actinolite on the contrary lies in long bands of several inches, with many crystals making up the mass, and all more or less in the same direction, but not making straight lines. They originally may have been made straight, and then bent by more recent movements. As the contact with the overlying formation is reached these minerals become more common and in some thin layers where the marble gives way to the typical Whitingham quartz-mica schist, make up 20 to 50 percent of the rock.

Micas are probably the most common accessory minerals, and several species occur. Stringers of mica, mostly muscovite and sericite, occur at all depths in the marble. Some are several feet in length and vary in thickness from one inch down, representing a variable layer or lens in the sediments. Other stringers are even more extensive and constitute layers many feet long and wide, but never of uniform thickness and rarely more than two or three inches. In such cases muscovite is not alone. In some horizons, notably toward the top, both at Sherman and near camp the muscovite is finely divided and scattered rather uniformly all through the layers. In such cases graphite accompanies the mica. The most striking occurrence of mica, however, is at h-30 in the pink marble. Here phlogopite in crystals from one-half inch diameter down occur in great numbers. They are characteristic bronze colored with submetallic luster, and yellowish brown by transmitted light. Single flakes, scores in one plane occur, also bunches of flakes and crystals, two or three inches across. When the rock weathers these bunches stand out as brown rosettes looking like a withered flower. Scattered through the pink marble they make very showy specimens. Phlogopite in some samples taken, constitutes as much as 25 percent of the rock. This is the only place where phlogopite was noticeable. Dale reports it in the quarry now under water southwest of Whitingham.

A green mica also occurs freely in the upper part of the formation. This is soft, brittle, nearly transparent, and coarser than much of the chlorite, in younger formations; but it probably should be called chlorite. It is mingled with the phlogopite of the last occurrence in large masses and is sprinkled through the marble at d-33. It occurs with actinolite at Sherman and in the upper transitional layers at S-24 near camp. Plate XIX-B.

Pyrite is common in minute crystals in the marble, but is nowhere noticeable. The largest crystals seen were scarcely one-sixteenth of an inch in diameter and they were never seen in aggregates, but finely disseminated. Quartz crystals occur near the upper transition zone probably due simply to the metamorphism of quartz grains in the sedimentary beds, as the latter became more sandy. Tourmaline occurs in many places in the marble. Black is the predominant color, but red has been seen. At h-30 black tourmaline crystals pierce through the chlorite in every direction in crystals one-third inch long and downward, and from one-thirty-second of an inch in diameter to scarcely visible. Iron stain in the weathering marble is rare. The pyrite is probably responsible for some of it.

Talc was found with chlorite and actinolite in the marble at h-30, but seems to be rare here and was not noted elsewhere. It may be secondary after the hydromicas or, better, after actinolite and tremolite.

At e-f-34 the marble is shot by a quartz dike and considerable mineralization has occurred. While this intrusion occurred long, long, after the making of the marble and will be mentioned in its proper chronologic sequence, it seems well to mention the quartz and tourmaline in the marble as a result of the intrusion. Little quartz stringers apparently of the same sort are found in the marble near camp in considerable numbers, and at Sherman XY-36.

It becomes obvious from the discussion of the last few pages that the marble varies visibly from place to place. Yet these are all within a narrow range and do not seem to indicate more than one formation. Because of the position of the folds of the marble with reference to the depth erosion has gone, the base of the marble has not been found. Drillings no doubt would find it and erosion may later uncover its lower contact, but that has not yet been done in our area. The thickest exposures are at Sherman, where fully 200 feet can be seen. It seems probable that if the whole anticlinal structure here could be seen, even where the bed of the river lies, we should be able to see two or three times as great a thickness of marble. We believe the structure and forms here make it clear that there is at least 600 feet of the marbles, but only 50 feet or so can be seen on the west side and probably not more than 300 feet on the east side. The river and its alluvium occupy and cover the middle part of the anticline.

In the Whitingham area the crests of the marble folds are from 300 to 400 feet above the highest marble exposed at Sherman. Thus probably if the Sherman folds were restored the marble would still be higher in the eastern area than at Sherman. Dissection, therefore, in this eastern area comparable with that at Sherman would no doubt uncover lower marble than shows at the latter place. That the top of the marble is much lower in some parts of the area than in some of these where it is seen, is obvious, for the rocks have been cut down along both rivers below the levels at which marble is seen in the hills south of Sadawga Pond, yet without exposing even the top of the marble. Necessarily the marble is, therefore, involved in the folds just as are the layers of rock above it. This interpretation is well supported by the fact that every occurrence of marble known in the area is in the crest of an anticline and that younger overlying rocks dip with it away from the axis of the structure on each side.

The Whitingham Schist.—This formation has been found immediately overlying marble in every occurrence of the latter where the contact could be found. It has been located in R-25, S-24, S-28, and W-32 on both sides of the marble dipping consistently away from the axis of the marble fold, in the eastern part of V-36, *i. e.,* on the western flank of the Sherman area of marble and doubtfully on the eastern flank also, in a dozen or more places in the Whitingham marble area, contiguous with marble. Because of these relations generally, all over the area we have mapped it in interruptedly except where marble shows through. Because it is so well developed here and because this is easily the largest area known, we have named the formation the Whitingham Schist from the township in which it here occurs. In four places lying almost perfectly aligned we found what seems to be the same formation. These outcrops are in the western part of our field at E-7, E-14-15 and D-E-16-17, D-21 and D-26. We considered two of these to be special phases of another formation higher up (the Readsboro) when they were first found. When their true relations became known we were forced to interpret them as Whitingham, for all four are perfectly consistently located if so interpreted, while if called Readsboro, a fault must be invoked to explain their occurrence here. We could find no other evidence of faulting. In the large area D-E-14-17 the anticlinal structure was finally found with opposing dips on east and west sides. Forest and drift cover so much of this area

that we could not connect the several outcrops, but believe if the truth were known, they would be found all to line up along the axis of a large anticlinal structure.

It seems reasonable to suppose, with the above distribution and structure, that this formation is continuous from one outcrop to another over the marble and under the next layers above. It would thus be wanting only when the marble shows through.

The Whitingham schist resembles notably certain layers in the Readsboro (figure 3), but differs strikingly in some characteristics. It should be called a quartz-biotite schist with calcite. Nearly half the rock is quartz in small even grains and nearly half is just as even grained biotite. In addition calcite occurs in crystals in many parts of the rock. Some hand samples effervesce freely in scores of tiny centers when bathed in hydrochloric acid, others very sparingly. All samples taken show calcite in spite of the fact that two were only one or two inches from the surface. The rock is even grained wherever seen and remarkably similar

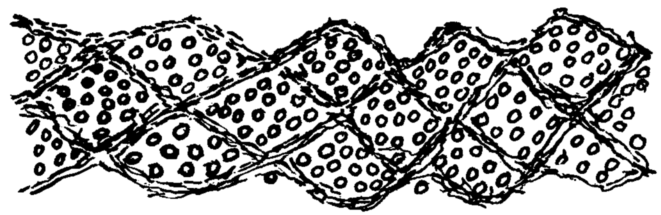

FIGURE 3. Pebbled Readsboro. A mesh of biotite enclosing bunches of feldspar and quartz which when weathered looks a little like a pebbly conglomerate.

in appearance from place to place. Pyrite crystals are rare, but are present, as confirmed by the brown weather stains where they have been oxidized. Muscovite and chlorite also occur.

The Whitingham formation has a thickness in S-24 of about 40 feet. Actual measurements are probably impossible. We found no place where they might be taken because both contacts were not found opposite each other. In S-28 it seems to be thicker than at camp and in the large Whitingham area it is certainly more than 100 feet thick. No thickness could be ascribed in the outcrops of the western part of the area because the base was not exposed. Obviously the formation thickens eastward, but since all the full-thickness outcrops are within an east-west range of three miles we cannot say what happens farther east or west from these.

In the squares e-f-34 southwestern corner of the large marble area, and near the road, a quartz dike was found cutting across both marble and Whitingham schist. This is the only dike noted in the latter. The dike was a good mineralizer, for in the Whitingham beside the dike are pyrite, red and black tourmaline, calcite, and quartz. In the dike is much black tourmaline.

The Whitingham schist has no sharp boundary below, but grades up from marble to schist. In the transition zone, which may be several feet thick is a wealth of chlorite and actinolite, as well as the essential minerals of both marble and schist. In some places these two green minerals make up almost the whole rock for several feet. Some very attractive specimens could be taken in S-24. The biotite of the schist seems to have been formed before the quartz. While actinolite is the most abundant amphibole along the contact at the camp outcrop, tremolite is by far the most abundant at the Sherman outcrop. Layers one-half to one inch in thickness of almost solid tremolite occur. Other layers consist almost wholly of tremolite and fine grained phlogopite.

The upper contact of the Whitingham with its successor is also a transition. Usually it is gradual and since both are mica-schists it is difficult to locate. The gradation covers from 5-20 feet of thickness. Either type is distinct enough, but the intermediate beds are truly neither Whitingham nor Heartwellville. The calcareous phase disappears first, then the percentage of silica declines and the texture becomes coarser. The change in mica is more abrupt.

Heartwellville Schist.—This schist was first seen in the hills above camp overlying the Whitingham and marble. Its identity with the rocks of the large area in the western section studied was not at first suspected, although every one of us had trouble in pointing out any difference between them. It was called the sub-Readsboro here because of its position, and the only real difference found was one of position. When it was discovered that the beds in the west called Heartwellville dipped below the Readsboro on both sides of the area our only distinguishing character failed and we all were forced to class both as one. Since the town of Heartwellville lies upon the large area it seemed but fitting that that name should prevail for the schist. The thrill of discovery caught many of the party when the true relations of the Heartwellville were made out.

The large area in the west is narrow to the south, but widens rather rapidly, until in the latitude of Howe Pond it covers about two miles. This width is maintained across the area northward and this type of rock runs off the area westward nearly all the way north of the pond. The formation dips under true Readsboro on the west, a short distance beyond the area, and northwest of Howe Pond, just as it does on the east near West Branch. Around Heartwellville and Howe Pond the drift covers all so deeply that we did not map bed rock. In four patches along the axis of the area as described under Whitingham schist the older rock protrudes through the Heartwellville.

Eastward from this large area the formation appears in many small outcrops. First in the steep slopes one-half to one mile

north of Readsboro along the road to Heartwellville many great boulders and probably ledges in place show in the steep valley wall. No authentic dips were taken here. Then one and one-half miles farther north in the top of the hill a small patch shows through. This area has east dips on the east and west dips on the west. North of the "square" in Readsboro, for a few hundred feet, in the rock slopes, the Heartwellville is found dipping at a low angle westward, and a few yards farther east it descends sharply to the east. This area may be traced southward into the east slopes of Lord Peak and one-half mile south of town. Up the nose east of town, beyond a narrow N-S strip of younger Readsboro schist outcropping conspicuously near the railroad yards occurs a long narrow area of Heartwellville in a distinct anticline. This is probably to be correlated with the structure across the river north in the eastern part of town, where the fold is high enough to expose the marble.

A few hundred feet farther east on this hill comes in the area which surrounds the Whitingham and marble of the whole camp area. Heartwellville schist is easily traced entirely across the ridge from river to river, in two bands each 200 to 300 feet wide, broadening a little perhaps northward. This area seems to extend across the river south into Lord Peak, and it can be picked up with ease on the north side of the river at camp and

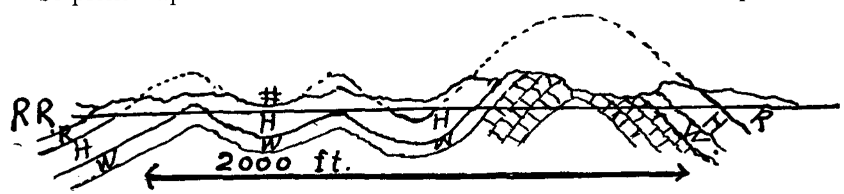

FIGURE 4. Structure section nearly east and west through new large power plant. RR = railroad level; dotted line = restored folds; irregular solid line above railroad = present surface. R = Readsboro; H = Heartwellville; W = Whitingham; block work = Sherman marble. ‡‡ = Power plant. Note frequency of wrinkles.

both bands can be traced back into the hills, the east strip much more successfully, the west mainly by boulders and by associated beds. The two bands converge and meet in S-23, and the crest of the fold where they meet pitches northward under the next formation at a rapid rate. The convergence of the two bands or strips testifies to the pitch even on the rapidly rising ground. The beds dip outward on each side.

Another area of Heartwellville occurs around the new power plant and southeastward. On the county line and the wagon and railroads is a small wrinkle which brings Heartwellville above railroad-level. Just east of the power plant is a similar small fold. These both pitch north into the hills and south so sharply that they were not found across the stream. Figure 2. Going on east beneath the power lines this formation rises again sharply in an anticline. The layers can be traced northward into the hills and around the end of the Whitingham and marble, and back southward on the east flank of the structure. The larger area surrounding Whitingham schist on the north and extending in two strips southward continues in the two strips for a mile and a half or essentially to the Massachusetts state line, just north of which they meet again and go under the Readsboro formation to the south. The Heartwellville thus completely surrounds the areas of marble and Whitingham in this (Sherman) locality. The river has cut out so much material that it has left the distribution rather in confusion, but the structure is clear enough.

Another area of Heartwellville surrounds the area of Sherman marble and Whitingham schist described from the Whitingham area. This border was not found every foot of the way. It was obvious at many points on the west side and around on the northwest, at one or two points on the north, in several patches on the northeast, rather continuously all along the southeast and across the south. Thick drift and swamp conditions conceal the rock in several places, timber interferes with study somewhat. We believe, however, that the mapping is not more than 100 to 200 feet in error anywhere around this area and usually much closer than that. In this whole area the dips are outward and carry the Heartwellville beneath the Readsboro.

Only one other area of Heartwellville was found and that is in some doubt. It may show in a small area on the hill about one-third mile west of the county line and one mile south of our northern boundary. This does not seem to be a reasonable place for the formation to show and no doubt is an error in identification.

This distribution taken with the structures to be described in later paragraphs, suggests very strongly that the Heartwellwill underlies the whole area except where the older formations are at the surface, and that in these areas it has been eroded completely away.

Mineralogy of the Heartwellville Schist.—This formation has but few minerals and two of them vary widely in their percentages. Quartz and sericite make up 90 to 95 percent of the rock. Specimens from A-18 are put at 96 to 97 percent sericite and less than 1 percent quartz, while one near the power plant is estimated at 7 percent sericite and 90 percent quartz. The former are very near the top of the formation, while the latter is probably near the base. At both D-27 and Q-27 sericite is estimated at 90 percent or over, and these are doubtless both near the base. Many samples show quartz and sericite nearly equal. We do not believe the proportions of these two minerals are definitely related to the zone in the formation. Apparently highly siliceous and highly micaceous layers can occur anywhere in the formation. Sericite is clear, silvery, shiny to delicate green in the lower and

middle parts and distinctly blue to blue-gray in the upper part. The latter is seen at A-18. At L-21 in the top of the Heartwellville we took samples in which the sericite was clear to green in color. At E-F-19 which must be near the base of the formation, beautiful silvery to green sericite makes up nearly half the rock. Color of mica seems to bear no relation to proportion of quartz and mica. Quartz is usually clear to milky, but pink was noted at D-27.

Garnets of a red, almandite type occur all through the formation, so far as we could discern, with the exception of the upper layers at A-18. They make up as much as 3 to 5 percent of the rock in many places and probably 10 to 15 percent in selected layers. They range in size from one-fourth inch down to tiniest specks, and some little beds, one-eighth inch in thickness are almost solid, tiny garnets. Tourmaline, too, is of frequent occurrence though not as widely distributed as garnets. It is always in black crystals usually long, slender, but at A-18 stocky. At D-27 crystals one inch long were taken. Perhaps they are a little more frequent in the blue sericite mica schist than in other forms. They seem to bear little relation to bedding, but pierce the schist in every direction.

A bronze or brown mica was noted in one or two percents at E-F-19 and at V-31. Graphite makes up one percent of the rock at L-21. This is near the top and is not related to the marble. Biotite was noted in several places in tiniest specks and flakes, occasionally parts of flakes that are chlorite at the other end. At E-F-19 it makes about one percent. Chlorite was noted at D-27, but only in about two percent and it may have been secondary after garnet, though this was not suggested by the specimen. It occurs in soft green flakes and in aggregates in several places.

An interesting occurrence of boulders found at J-31 contains more chlorite than most of the formation. It also has sericite, quartz, magnetite, in very small octahedra and ilmenite plates in the chlorite bunches, and fine crystals and bunches of crystals of feldspar, apparently albite, though no optical tests have yet been made. We have samples to be further studied. These boulders were nearly a mile beyond (southeast of) the Heartwellville border. But northward back in Heartwellville, ledges of this same rock occur. It does not seem to be abundant. It was first noted as probable Readsboro boulders and later was found as beds in the lower formation.

In thickness the Heartwellville seems to decrease rather consistently eastward and probably southward. The thickness cannot exceed 300 to 400 feet in most of the outcrops east of Readsboro, for it occurs only in narrow strips of 500 to 800 feet wide, with dips usually of less than 60°, and in the eastern area of less than 45°. There is in almost every area some wrinkling which causes repetition of part of the layers. In the western part, if there were no wrinkling, one would readily estimate 3,000 feet, but there is no possibility of the thickness being half as great as that, for on each flank of the large anticline are several folds from a few feet to a few hundred feet wide. Probably 1,000 to 1,200 feet is thickness enough to ascribe to the formation anywhere in the area.

This formation lies in a large anticline in the western part and several smaller ones in the central part and each fold has wide, broadening a little perhaps northward. This area does not smaller folds all over its back. The smaller folds have wrinkles of a few feet in width all through their structures. The large anticline in the west pitches sharply southward so as to carry the whole formation down out of sight beneath the Readsboro a mile from the edge of our area. In the town of Readsboro and eastward beyond camp, fold after fold occurs. Four or five are known, the largest lying farthest east and sending its eastern limb down below Readsboro schist just east of camp. These folds like those on the big anticline in the west are adorned with smaller folds and wrinkles down to a foot or so across. Every fold in and east of town pitches both north and south so as to carry its Heartwellville down and out of sight quickly. At least three folds occur in the Sherman area, two small ones near the county line and the larger one with the marble core exposed. Figure 2.

In the last area to the east, the wrinkles or folds mentioned in the discussion of the marble and Whitingham Schist are repeated in the Heartwellville cover and borders. The ragged or zigzag outcrop on both north and south ends of the area mean folds. Where the formation penetrates (on the map) the Whitingham area there is a syncline, and where tongues lead out into the Readsboro there are anticlines. On the extreme southeast corner of this large area is a small anticline in the Heartwellville high enough to bring out the Whitingham, but not so high as to expose the Sherman marble. Each of these folds pitches and runs under both north and south. And the whole group of folds is contained in one large anticline whose Heartwellville formation spans at the surface one and one-fourth miles. The structure is so steeply pitching that its whole length as shown by this formation is not more than one and one-half miles. Of course it is longer in the Readsboro and even in this formation below the surface.

Judging from the samples of the Heartwellville structure we have, and from those in the overlying Readsboro where the former is covered, the Heartwellville is everywhere intricately folded and plicated into small and large pitching synclines and anticlines.

No faults of mention were found in it, and the dikes cutting it will be discussed later under igneous rocks. As stated under Whitingham the contact at the base of Heartwellville is a transition zone, but at the top the boundary between it and Readsboro part, if there were no wrinkling, one would readily estimate 3,000 feet, but there is no possibility of the thickness being half as great as that, for on each flank of the large anticline are several folds from a few feet to a few hundred feet wide. Probably 1,000 to 1,200 feet is thickness enough to ascribe to the formation anywhere in the area.

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No faults of mention were found in it, and the dikes cutting it will be discussed later under igneous rocks. As stated under Whitingham the contact at the base of Heartwellville is a transition zone, but at the top the boundary between it and Readsboro

Geologic map. North line is parallel of 42° 50′ N. West line is meridian of 73° W. South line is Mass.-Vt. state line. East line is Whitingham-Halifax township line. Last two do not run on cardinal directions. Symbols: Vertical ruling = Sherman marble; circles = Whitingham schist; horizontal ruling = Heartwellville schist; oblique NE-SW = Readsboro schist; oblique NW-SE = Halifax schist. Black = basic dikes diorite; Dots = acid dikes; Q = large quartz dike; White = drift or water covered, partly Deerfield valley.

is rather sharp. Actual contact was located in many places. In O-26 is a typical occurrence of this contact. Here the dip is west and the Heartwellville goes under very neatly and definitely. At L-M-21 just north of the bridge is a very clear case and easy to find. Here the dip is steep to the east and the Heartwellville goes under. Our mapped contacts were observed rather frequently though, of course, not continuously. East of camp in S-T-24 the contact can be traced many feet, with the Heartwellville, garnetiferous, blue mica, phase going under.

The Readsboro Schist.—This formation has much the largest outcrop of all studied. In fact it occupies more than 60 percent of the area under consideration. Unlike every other formation, its outcrops are continuous except for some strips along its eastern side where it grades into the next formation above.

Entering the area from the west it may be found along the southern half of our boundary line in a strip widening southward as far as the Heartwellville shows. It can be found all the way along our southern boundary, except for a few hundred feet each side of the Deerfield River, where older rocks are at the surface, until two miles beyond Jilson Hill where the Halifax schist comes in, and the Readsboro goes under. From a mile east of Heartwellville village its outcrop is continuous across our entire northern boundary. It is interrupted by the areas of older rocks described, and by a considerable number of intrusions of igneous rock to be considered later. The eastern border of the Readsboro is somewhat ragged owing to the fact that typical Readsboro and typical Halifax are interbedded, often rather intricately, in a strip a mile wide running obliquely from N-E to S-W through the village of Jacksonville.

It is nowhere covered in our area except by the Halifax in our southeastern corner, and by drift and water in several considerable patches. In mapping we have continued the Readsboro symbol under all drift and water unless we had good reason to believe something else might show if cover were removed. We believe older rocks could be seen in the Sadawga Pond area and more granite dike material beneath the large reservoir a mile or so north of Davis Bridge site. See map, Plate XX.

The Mineralogy of the Readsboro Schist.—This formation is essentially a quartz-biotite schist with considerable variation, both in texture and general appearance and in mineral composition. Quartz usually makes up at least half of the rock, in places as much as 80 to 85 percent. Biotite may run as high as half, but usually constitutes 25 to 40 percent. Sericite and muscovite occur also, small masses of chlorite and one to ten percent of feldspar in many places. In fact much of the rock is so feldspathic as to be a gneiss, and it becomes more so northward. Hornblende, and in some beds, calcite make up most of the rest of the formation. Magnetite in tiny black specks, scattered or in bunches is common, but constitutes less than one percent. Few garnets, tourmaline, and pyrite crystals were noted. Garnets were found at Q-23 in a pasture in a rather typical phase of Readsboro and again near the railroad station as noted below, possibly in a few other places, but they are rare in this formation. These two occurrences may well be in the same beds in a low horizon.

Tourmaline and pyrite in the Readsboro are usually associated with intrusions and will be described under that heading and as a result of mineralization.

Near the base in square N-21 a mile northwest of Readsboro an even grained, gray, feebly banded sample was taken with the following estimated percents of minerals: Quartz 54, biotite 25, muscovite 10, calcite 10, miscellaneous 1. Fragments effervesced freely in many places in cold hydrochloric acid. A little farther east up the hill between the roads, S-21, but probably not much higher stratigraphically for it is right on the axis of the fold, the gray-green rock splits very evenly and readily, is much more siliceous, has about two percent biotite, and 12 percent silvery to green sericite with no calcite. The biotite is in tiny black specks. At W-24, probably a little higher stratigraphically, the formation is gneissic in appearance. Quartz and biotite are about equally abundant, calcite about 5 percent, feldspar and sericite 1 or 2 percent each. Calcite, according to the acid test, is usually absent, not more than one sample in 6 to 8 effervescing at all even hot.

At Q-26, on the nose of the hill east of Readsboro, hence just above the Readsboro railroad station, occurs a large exposure of this formation. It dips steeply westward and is on the flank of the first anticline crossing the hill. The Heartwellville outcrops a very short distance west and less than 500 feet east, hence this must be near the base of the formation yet not nearer probably than 200 feet. It shows also in the stream bed below the dam. It is here composed almost wholly of quartz and biotite about half and half with a small percentage of muscovite and garnet. Perhaps the most conspicuous feature of this exposure is the very good cleavage. It probably is nearly along bedding planes, hence is more due to mica layers than to pressure. The grain here is even and the color a uniform gray. It is one of the most valuable phases of the Readsboro.

A group of beds very similar to this shows in the railroad cut near the curve a mile upstream. In the latter, muscovite prevails over biotite.

At q-27, q-18, and s-t-11 samples were taken. They are still some distance from the top, but higher than any others described. The first is gneissic and massive, dark colored and crumpled a little. Its minerals are estimated as follows: Quartz 50 percent, biotite both black and brown 42 percent, muscovite 6 percent, chlorite 1 percent. At the second the rock is much more distinctly banded, splits better and contains quartz 65 percent, biotite 12 percent, green to silvery soft sericite 20 percent, and feldspar 2 percent. The third sample, still on about the same horizon, for the strike here runs northeast, resembles the last but splits even better. It seems to be about half and half quartz and biotite, with 1 or 2 percent of feldspar and a similar amount of tiny crystals of black iridescent magnetite. No igneous rock was found near, but that does not preclude the possibility of its presence just under cover to aid in developing the magnetite.

At p-27, certainly a little lower than q-27, for the dip is east all the way between, the rock is lighter than at q-27, more gneissic and carries about 80 percent quartz, 10 percent biotite, 5 percent muscovite and greenish sericite, 2 percent hornblende, and 1 percent of chlorite. There seems to be no systematic gradation in the amounts of quartz and biotite, but the calcite is apparently confined to the lower part and the rare feldspar is higher up. Because of the multitudes of small folds it is practically impossible in most places to tell just where one is stratigraphically.

At q-21 the rock is even grained, light and dark banded, and has about average composition, but contains much magnetite, estimated at 10 percent, in beautiful iridescent crystals of varying sizes from one-eighth of an inch down. There is noted here also 2 percent of feldspar. The magnetite is coarser grained and more abundant in the lighter more siliceous layers. A quartz dike cuts through the Readsboro in this square and is no doubt in part responsible for this magnetite, for the latter becomes more abundant toward the dike and occurs freely in it.

At k-4 there is an outcrop of a blue sericite schist very much like the typical blue schist of the upper Heartwellville. When first discovered this rock was mapped as belonging to that formation, but its true relations were later deciphered and it is known to be a layer 20 to 40 feet thick in the Readsboro. It was traced through three squares in the direction of the local strike N. 30° to 35° E. and found to be both overlain and underlain by true Readsboro. It dips consistently northwestward with the adjacent beds and can undoubtedly be accepted as simply a bed in the local formation. This bed, however, so closely resembles the Heartwellville that it carries about 1 percent of black tourmaline prisms and twice as much of garnet, some crystals of which are nearly one-half inch in diameter.

At O-7-8 a very similar occurrence is found. The amount of quartz is a little larger and garnets were not recognized, but the rich iron stain and the chlorite may be the remains of the garnet. Here typical Readsboro was found both above and below and the thickness of the blue rock was not over 25 feet. The whole structure dips eastward and the same beds were seen on ground 200 feet lower and 800 feet farther east in striking ledges.

Here again true Readsboro is both above and below. It should be noted in this connection that the patch of Heartwellville mapped in N-O-11-12 is an anticlinal structure and the blue schist dips both east and west on opposite sides.

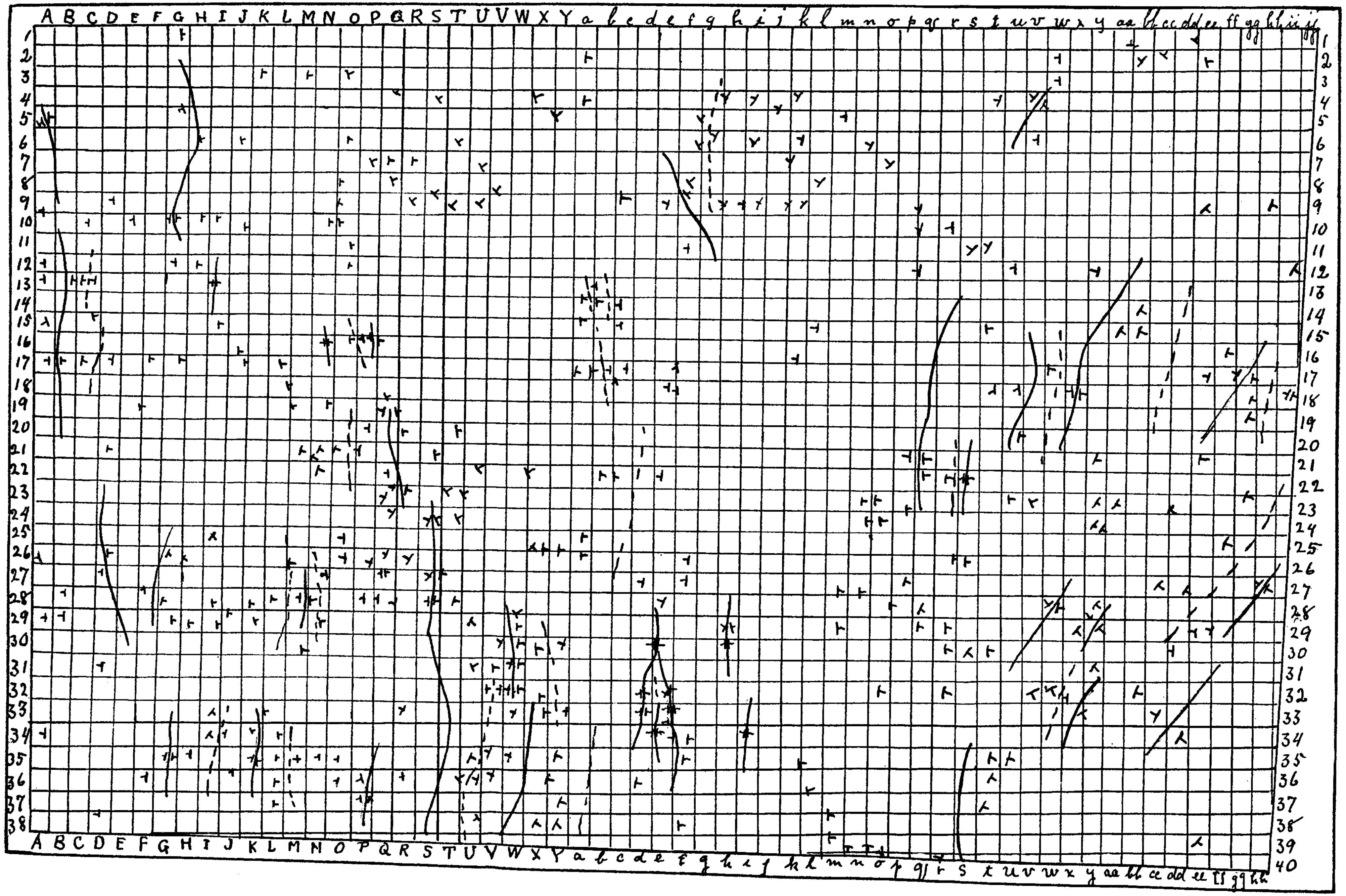
It seems to us as we look the whole problem over that the Heartwellville-like layer 20 to 40 feet thick stands for a reversion to true Heartwellville sedimentation after several hundred feet of Readsboro had accumulated.

Another phase of the Readsboro which needs description is known as the "pebbled" rock. At a short distance it looks like a conglomerate when weathered a little, and like a banded porphyry when fresh. The layer has been seen in several places and is believed to be about 600 to 700 feet above the base of the formation. This determination has been made above the Sherman marble to the east up the hill where the pebbled phase occurs nearly at the top of the steep slope and almost on the state line, perhaps a half mile back from the river, also along the river a mile above Readsboro. The rock consists of biotite, quartz and a little feldspar. The biotite is arranged in wavy layers and the other light colored minerals in knots between the mica layers (figure 3). Thus the dark mica surrounds the nodules of quartz and feldspar. On weathering, the harder quartz stands out a little in relief. The probable thickness of these layers is 30 to 50 feet.

It has been impossible to arrive at any concise measurement of the Readsboro, but estimates in various places have been made. In the hill tunneled through from the big Whitingham dam to the power plant, a continuous east dip is found from the river almost to the very summit. This is a horizontal distance of a mile. The succeeding formation is not preserved on the hill, hence the whole hillside is Readsboro. If the layers were horizontal through the hill there would be 950 feet in thickness; but they dip into the hill at an angle of 30° to 35°, which would give a thickness of about 4,000 feet. How much Readsboro has been eroded from the top of the hill cannot be known. How much Readsboro goes down in east dips on the east flank of the anticline and west of the river, cannot be accurately known, and also how much is repeated by minor folds is not known. But the east dips over the whole stretch from the crest of the camp anticline to the top of the tunnel hill are very constant and very few, even minor wrinkles are known. Hence it seems perfectly safe to assume that there are at least 4,000, possible 6,000, feet here (figure 4).

The dips are similarly constant and eastward for a mile on the east slope of Jilson Hill. Here the beds go down at an angle of about 30° to 40° for more than a mile horizontal, which would give a thickness of 4,000 to 5,000 feet. Few wrinkles occur here to complicate the problem. We believe, therefore, that

PLATE XXI.



Represents area mapped, ruled in small rectangles each square was one-sixth inch = (one-sixth mile) in note books. All references in text to localities by coordinates, can be located on this grid; dips and strikes are shown. Solid lines among symbols indicate anticlines, dash lines indicate synclines. The main large structure does not show on this grid. Read with geologic and topographic maps.

a thickness of 4,000 for the Readsboro is reasonably safe. We have no evidence that it varies greatly in thickness from place to place, except as it has been removed in places more or less completely by erosion. It is probably not all present except at such places as it goes under the Halifax, the next younger formation.

Structure of the Readsboro.—In as much as the Readsboro outcrops all round the camp marble area with its Whitingham and Heartwellville, it certainly has an anticlinal structure here. In a similar way it surrounds the marble areas as a whole upon the hills east of Sherman, witnessing to an anticlinal structure there. In the high hill between Readsboro and Whitingham through which the power tunnel pierces the structure, it is distinctly synclinal, but the syncline is shallow and, emerging on the south end of the hill at the road, almost runs out east of the power plant. At the north end of the hill the axis of the syncline bears westward and rises and then passes into several small synclines and anticlines on north of Davis Bridge site. Thus in the hill one broad syncline with some lesser wrinkles dominates the structure for a width of nearly two miles, but at both ends the trough comes up and frays out into a group of lesser folds. Along the flanks of this larger syncline the strikes converge southward in the southern half, and northward in the northern half.

In the area north of Readsboro for two miles the structure consists of a series of small folds both up and down, the strikes are convergent and divergent in alternating succession. Thus we may interpret the folds as pitching. This pitching is often steep, carrying a whole structure down in less distance than a mile. This is strikingly shown in the borders of the Whitingham marble area. Southwest of Readsboro the main structure is synclinal, but in it are several lesser pitching synclines and anticlines. More than that, a structure starts down as a pitching anticline, weakening as it goes and gradually becomes very small, and then a syncline begins on the crest of the anticline and increases in size while the latter continues to fade out. Soon the axis is distinctly that of a syncline and the reverse structure has disappeared. This type of transformation was elusive and distressingly confusing until we really saw what was happening. Then their pursuit became fascinating. Nearly every structure we worked was of the pitching sort, wide in its central part and tapering at both ends, and in scores of cases we proved the change from one structure to the opposite along the axis.

Not only are there such structures with dimensions of thousands of feet, but there are many of tens of feet all over the backs of the larger anticlines and in the synclines, and again the strata in these lesser structures are plicated in a much more minute but identical pattern so that one can gather hand specimens of one or two feet length in which two anticlines at one end and a syncline between, become two synclines at the other with an anticline between. The plications are not always simple and schematic, but in places are most intricately contorted and twisted. In the borders of Whitingham village, northwestern part, one can see some beautiful illustrations of these quirks.

Many dikes of several kinds occur in the Readsboro which will be discussed in a later section.

The Readsboro has a pretty definite boundary with the Heartwellville below and very little interbedding near the contact, but that between the Readsboro and the Halifax above is of an entirely different character. These two schists are distinctly different, one is gray, the other black to dark green, one highly siliceous, the other rarely siliceous, one resistant and the other crumbling and easily disintegrating. But over a strip a mile or more in width along their mutual boundary the two are usually thoroughly interbedded.

At Jacksonville, for example, green chlorite schist of the Halifax type occurs west of town and gray siliceous rock of the Readsboro type occurs almost a mile southeast of town. In the hills one and a half miles southwest of town, six beds of chlorite schist 100 to 600 feet thick alternate with as many, and as great, beds of typical Readsboro. Another mile southwest five lenses of Halifax occur in otherwise solid Readsboro, while three miles northeast of Jacksonville, on the Halifax-Marlboro township line and just beyond the road leading south to West Halifax five lenses of Readsboro occur in typical Halifax schist. The latter type is almost continuous for a half mile west of these lenses. Each lens is 100 to 300 feet wide and one-fourth to three-fourths mile long. This illustration is entirely outside the area shown on the map. Besides such larger interbedding as this described there are many short, slender lenses of each kind in the other. The transition is never by easy gradations, but by alternations of the two kinds with each type becoming rarer away from its main area as the other becomes more abundant until the change is complete.

The Halifax Chlorite Schist.—The chlorite schist occurs in the eastern part of our area with a strike of NN-E-SS-W. In the southern part, along the state line it has a breadth of over two miles, but its strike is such that in the northern part it runs off the map east and does not cross our north line at all. Thus it may be said to have in our area a right triangular shape with base on the south of two and three-fourths miles, long limb on east of six miles and hypotenuse running through Jacksonville. This shape has no relation to the structure. The dips are consistently eastward, though locally reversed, and the strike is true N. 25° to 30° E., which corresponds roughly with the hypotenuse of our triangular area.

Since the Halifax is the youngest formation and the Readsboro dips eastward under it all along their mutual contact, it can nowhere be covered with bed rock.

Scores of outcrops occur on hills, ridges, in road cuts and, occasionally, in stream beds. While it is not very resistant, its waste, mostly mica, is easily washed away and outcrops are frequent. Drift and meager products of its own decay mantle it most of the way, but probably rarely deeply.

Its mineralogy is generally simple. Dark green chlorite is the characteristic mineral. The samples discussed here show the similarity of the formation, whether well into the chlorite or well into the Readsboro. At s-30 beside the road nearly two and one-half miles southeast of Whitingham and almost a mile on the Readsboro schist side of the mean boundary between it and the Halifax, the rock is estimated to contain 75 percent chlorite and 25 percent quartz, all fine, even grained, the chlorite usually in tiny prisms. At w-32 near the border and almost a mile from the last, the estimated constituents are chlorite 80 to 85 percent in prisms, quartz 10 to 15 percent fine, even grained and straight, even bedding. At d-20 in the border but possibly nearer Halifax than Readsboro schist, one mile straight south of Jacksonville, the minerals are chlorite 84 percent in prisms and plates, quartz 15 percent with the same fine, even grain.

At cc-27 a half mile into the Halifax the rock is crumpled sharply and is in line with the disturbance east of Jacksonville. Minerals are chlorite about 90 percent, with quartz about 9 percent. Rock is just as fine, even grained as any.

At jj-25 one and one-half miles into the Halifax and about two miles down valley from Jacksonville, two samples were taken. One is estimated at quartz 50 percent, hornblende 5 percent, chlorite 40 percent, garnet 1 percent; the other, quartz 50 percent, sericite 45 percent, chlorite 4 percent. The chlorite is coarser than usual and the sericite is quite coarse with white to shiny silvery color.

A band in part richer in hornblende, but probably the same horizon, occurs in w-32 in the midst of the interbedded material. Two samples taken are estimated as follows: No. 1, hornblende, mostly in rosettes, with slender crystals often one inch long, 10 percent, garnets 1 percent, quartz 60 percent, sericite 25 percent, other micas 2 percent; No. 2, hornblende 30 percent, quartz 40 percent, garnets 1 percent, feldspar 3 percent, chlorite 25 percent. The former is coarse grained, the latter fine, even, and nicely bedded.

A similar band of hornblende schist occurs at ee-25 near the top of the ridge, but a few feet down on the east side. This is believed to be the same bed as the one described in previous paragraphs from jj-25 and from w-32. It has a similar strike and dips like them to the southeast, but there is a small fold between them and this occurrence.

Like the lower formations this schist has been shot with igneous material and locally modified, but that matter will be more fully treated under "Igneous Rocks."

The Halifax schist is probably more homogenous and similar over its whole area than some of the older formations. We did not become familiar with the next formation above, which outcrops farther east, and do not know the nature of the contact on that side. We have found variations from the true green chlorite schist in several places east of the line placed as our farthest boundary. Whether they should be separated as a new formation our studies are insufficient to determine. Possibly a small part of the southeast corner of our area merits a new formation name, but we do not feel justified in applying such a name without more study of the succeeding rocks.

The Halifax schist is probably 2,000 to 3,000 feet thick. It may be even more. Its complex structure and similarity in composition make its thickness difficult to estimate and the fact that we are not familiar with its upper contact precludes any positive statement as to its thickness, nor do we know anything of any differences in thickness.

This schist, while dipping generally eastward from a strike of N. 25° to 30° E., is as intricately folded, crumpled, and mashed as any part of the section. A fine, wavy structure occurs extensively in cc-*27* and out therefrom along the strike in both directions. The wave crests are one-fourth to one-half inch apart and are not continuous, but run into each other just as such plications have in the older beds. Within six inches of length a fold may run into its neighbor on each side or divide into two and reunite, or change completely from a synclinal wrinkle to an anticline. This minute plication is involved in larger folds of similar pattern, whose dimensions may be 20 to 50 feet in length and 2 to 3 across, and these in turn in still larger folds 200 to 300 feet across and a half mile or so in length.

One larger fold probably overturned, certainly badly confused and mixed up occurs northeast of Jacksonville. As we saw it one end is in the hill one-half mile east of the village and the other end some two miles northeast along the row of hills. The mashing has been severe along this zone. Possibly there is more than local faulting, but we do not think there is more than a few feet of displacement in any one place. There seems to be a number of local slips and the fold seems to be overturned. We reserve, however, a final interpretation of this structure until more field work can be given it. Perhaps the actual conditions cannot be disclosed with the mantle over it as much as at present.

Correlations of the Vermont Section with that of Adjacent Massachusetts.—We are loath to make correlations with the splendid work of Professor B. K. Emerson[1] and others, for in some respects we do not agree. Our work was largely completed before the above bulletin came to our hands and no attempt has been made in the field to correlate. Our mapping was done independently, not one of the party had ever seen Emerson's map of Geology of Massachusetts and Rhode Island until our map was wholly completed. Our petrographic studies, however, have all been gone over with the map in hand. The similarities between our descriptions and those of Mr. Emerson are interesting, the differences often striking. Our interpretations of relative age and succession of rocks and of structures agree very satisfactorily. Our stratigraphic subdivisions are at some little variance, but probably no more than might occur in tracing the several miles between his types and ours.

[1] Emerson, B. K., U. S. G. S., Bull. 597.

We believe, however, that it is best to state just what we have found even if it does not wholly agree with Massachusetts findings, make as accurate correlations as are possible and leave as little confusion as may be, reserving a final correlation to later studies. Probably some of the Massachusetts lines not yet known in Vermont can be traced across into our area, even though we have not succeeded in picking them up, and possibly some of our lines not yet recognized in Massachusetts can be traced across the boundary by starting in Vermont.

Massachusetts Section.		Vermont Section.	
Hawley schist and its hornblendic lenses,	2,300 ft.	We did not go far enough east to find it.	
Savoy schist,	3,300 ft.	Halifax schist,	2,000-3,000 ft.
Chester amphibolite,	400 ft.		
Rowe schist,	4,000 ft.	Readsboro schist,	4,000-6,000 ft.
Hoosac schist,	4,000 ft.		
Greylock schist,	1,500-2,000 ft.	Heartwellville schist,	1,000-1,200 ft.
Bellowspipe limestone,	?	Whitingham schist,	40-100 ft.
		Sherman marble,	600 ft.

By placing our map and Emerson's in juxtaposition, the equivalency of Hoosac in Massachusetts and Readsboro in Vermont is established. In the same way the Savoy and Halifax are equivalent. By position then the Greylock and Heartwellville are essentially equivalent, but our Heartwellville goes below the Readsboro southward in every occurrence before it reaches the Massachusetts line. The Emerson map has nothing corresponding with our Whitingham for the Bellowspipe limestone immediately underlies the Greylock. On the basis of position and character of rock we place our Sherman marble equivalent essentially to Bellowspipe limestone.

Apparently our section omits the Rowe and Chester schist, but we find in our Readsboro, material of a lensy character and not continuous enough to map as separate formations, which on mineralogic grounds might be considered equivalent. Thus the correlation is workably complete.

Some minor differences in mineralogic composition remain to be pointed out. The discussion will take up the formations in order of age, beginning at the bottom with the oldest—Sherman marble.

The Problem of the Sherman Marble.—Since the Sherman immediately underlies the Whitingham and Heartwellville and since the latter is equivalent to the Greylock schist, our Sherman is to be compared with the Bellowspipe limestone. This limestone as described by Dale[1] is "a series of limestone strata and calcareous (sometimes non-calcareous) schists.—In places the rock is quartzite" and Emerson[2] says, "a subordinate, impure limestone which grades (downward) into the Berkshire schist."—It includes the quartzite of Dale. (See reference above.)

Dale continues (p. 148), saying, "the micaceous element frequently predominates, making the rock a calcareous schist and in several localities the calcareous element disappears altogether." This is true of the Sherman in minor lenses, but not in any large bodies. He mentions galena, sphalerite and pyrite; we have the latter. We found none of the beds of gneiss among the calcareous layers as in the Greylock region. Quoting from Wolff, who made microscopic studies of this rock, Dale continues, "a bluish gray, finely crystalline limestone, composed of calcite grains and quartz grains," the Sherman rarely has quartz, but it has more mica than Wolff seems to find. His abundance of graphite is well balanced by our generous crystals and flakes at Sherman. At Greylock the marble contains feldspar, microcline and twinned plagioclose, but without petrographic examination[3] we have been unable to find any feldspar. Wolff reports limonite frequently; we have it but believe it is largely pseudomorphic after pyrite or simply in unorganized masses left after the oxidation of the sulphide.

We have nothing approaching a quartzite, but the limestone from which the Sherman was made must have been impure and even siliceous. The present mineral content points both to aluminous and non-aluminous ingredients. Iron was no doubt present in some beds in addition to the pyrite for both actinolite and phlogopite are now present in the marble. Likewise silica must have been present in the limestone to furnish the acid radical for tremolite and actinolite. It is generally believed that except in contact metamorphism very little material is actually added to sedimentaries in making schists and marbles.[4]

The Identification of the Whitingham.—The equivalency of the Whitingham schist is in more doubt. The fact that it contains calcite in some layers, and that it is interbedded along its contact with the Sherman may be reason for correlating it with the upper part of the Bellowspipe. On another count, however, it seems not to belong with our marble, for it runs some 50 percent quartz (metamorphosed quartz sand grains) and is rich in biotite,

[1] Dale, T. N., Mon. 23, U. S. G. S. (1894), p. 180.
[2] Emerson, B. K., Bull. 597, U. S. G. S. (1917), p. 40.
[3] The microscopic study of the rocks of this area is contemplated, but the sections are not ready yet, hence the work could not be done for this report.
[4] Bastin, E. S., Jour. Geol., Vol. 17 (1909), pp. 445-472.

both of which are rare in the marble. It does not in our area resemble notably either its bed or cover. It seems best in Vermont to map it separately for wherever it should occur it was found and in each case characteristically developed.

There are occasional crystals of white, milky feldspar and this with its calcareous character may be sufficient to establish its relation with the marble. If truly correlated with the Bellowspipe, it represents the more quartzitic and granulitic phases. In the Greylock area the limestone is found to be interbedded with quartzite and to contain stringers of gneiss, but in our Readsboro area the calcareous and siliceous phases are better segregated, the latter occurring mainly above the former. Because our upper part seems so distinctly different in character we believe it should be here mapped separately, the more so that it is not exposed anywhere continuously from our area to the Greylock exposures.

The Problem of the Heartwellville.—The identity of Greylock and Heartwellville schists is well established, both by position, as shown above, and by mineral composition, structure and texture. Dale (Wolff)[1] and Emerson[2] describe the Greylock as a much foliated and crinkled dark mica-quartz schist in which muscovite (sericite), and chlorite predominate, but in which are found locally biotite, magnetite, ilmenite, albite, tourmaline and even calcite in a number of places. Our description agrees well with theirs, except we have not found calcite, save in one place near the top of the Whitingham, even when reasonably fresh material was examined with acid, but we do find garnets widely scattered through the formation and usually of the almandite type.

In Dale's paper, p. 186, is described a feldspathic phase of this schist as "consisting of numerous squarish albite crystals, rarely in simple twins, crowded closely together, but surrounded by interlacing fibers of muscovite, chlorite and biotite with magnetite grains and many tourmaline needles. Quartz occurs rarely, in little grains or aggregates. The biotite and chlorite are often in separate masses, but often pass into one another in the same piece." This description might be applied verbatim to a sample taken at J-31 and occurring in ledges a mile or more northward. The rock could be recognized perfectly from the description of the Massachusetts occurrence.

The Greylock schist is not to be correlated with the Savoy schist as is done by Emerson[3] in his older work and even suggested in the later publication. The structure and the sequence within the structure establish the Savoy as much younger. Al-

[1] Dale, T. N. (Wolff, J. E., petrographer), loc. cit., pp. 186-188.
[2] Emerson, B. K., loc. cit., p. 40.
[3] Emerson, B. K., Monog. 29, U. S. G. S. (1898), p. 18; Bull. 597, U. S. G. S. (1917), p. 40.

though there are some striking local resemblances, such a correlation is clearly impossible by position of strata.

The anticlinal structure so clearly shown on Emerson's map in Monroe and Rowe townships of Franklin County, Massachusetts, is even better evidenced in southern Vermont. It is on the basis of this broad anticline with its opposing dips that the relative ages of the formations are established, and until this structure was delineated no way was known to arrive at the relative ages. When consistent dips on both sides were found all along it, the ideas of isoclinals, and monoclinals, and strike faults were all laid aside. It is this unity and continuity of structure in the Vermont and Massachusetts rocks which helps to secure the correlations made above and yet to be made.

Further Dale (p. 188) speaks of numerous folds (obviously small because all in so small a space) sometimes compressed and overturned, also of thickening of layers in consequence of plications, and of a coarsely foliated and a wavy structure. All these terms apply admirably to the Heartwellville of the Readsboro vicinity. The minute and gross plications and also the small and large anticlines and synclines of our area seem to be repeated in the Greylock area.

The estimates of thickness are remarkably close together considering the condition of the rock.

The Equivalents of the Readsboro.—As already suggested, on grounds of position the Readsboro corresponds best with the Hoosac schist, but we seem also to have included in our Readsboro the Rowe schist and Chester amphibolite. Let us consider the Hoosac first. The Readsboro might well be called a gneiss or at least a felspathic schist, and this becomes more and more true northward even beyond our area. Emerson[1] quotes earlier workers in both Massachusetts and Vermont to the effect that the formation in question becomes schistlike as the state line (Mass.-Vt.) is reached from each side, the formation being clearly gneiss in southern Massachusetts and north from Readsboro to Wilmington in Vermont, but decidedly a schist on the Massachusetts side of the line.

An earlier statement bearing on our incorporation of Rowe and Chester in the Readsboro is found in Emerson's Old Hampshire County, p. 69. "The Hoosac is here (on the road, Monroe to Rowe, Mass.) a dark sub-porphyritic, gneissoid biotite-mica schist. Farther on it swings round to run N. 20° E. and dips 20° E. and crosses the town line with the most westerly of the roads from Rowe to Vermont, far to the west of the point where, upon the Vermont map the corresponding boundary is made to cross the state line." Obviously some mapper of Vermont geology may rejoice in our delineation of the Vermont top of the Readsboro.

[1] Emerson, B. K., Mon. 29, U. S. G. S., pp. 67-68.

PLATE XXII.

Bouldery stream bed of West Branch Deerfield River a mile or two above Readsboro. Note rock wall on right and great boulders in the channel. A youthful stream.

We find the Readsboro in Wilmington township fully as feldspathic as the Hoosac is found to be in Massachusetts south of the schist phase near the state boundary, and somewhat feldspathic even around Readsboro. We find in the literature no mention of calcite in the Hoosac except that quoted by Emerson[1] from an old Vermont state report, which says, "In Whitingham and Readsboro there is a large amount of dolomite and saccharoid limestone present in the gneiss in the form of beds." We have shown in previous pages that these beds all belong to the Sherman marble, at least two formations below the Hoosac or Readsboro. We have found, however, a few small calcite crystals in the formation at scattered places even farther north than either of the towns mentioned and up to 10 percent in N-21 north of Readsboro.

According to Dale[2] and Emerson[3] the Rowe schist is a monotonous, pale green, or light gray hydromica schist; both call it quartzose, magnetitic and chloritic. This composition agrees well with the Readsboro. We described the formation frequently as gray-green. Because of these many similarities we could not find grounds in Vermont for subdividing, so drew no line corresponding with that in Massachusetts between Rowe and Readsboro schists.

Emerson[4] points out that his Massachusetts section, Hoosac to Hawley schists, is continuous and conformable. This section runs from our base of Readsboro beyond our area eastward. We agree that these beds are wholly conformable. Moreover, we found the three beds below this section wholly conformable among themselves and with the Readsboro above. Therefore, we cannot agree with Emerson[5] where he says, "the Chester amphibolite occupies about the position of the Bellowspipe limestone and may be its time equivalent." No doubt the problem looks quite different in the Vermont setting from what it does in the Massachusetts surroundings. This Chester amphibolite should reach into our area about where West Branch Brook flows out, *i. e.,* a mile east of Jilson Hill or two and one-half miles west of the Halifax-Whitingham township line. We have mapped typical Readsboro a half mile farther east than this place and feel pretty sure of our ground from the Vermont side. We have found lenses and narrow strips, however, of hornblende schist in many places interbedded with the Readsboro in this vicinity. We also recognized the same lensy, interbedding in Hogback Mountain and Higley Hill and vicinity 8 to 11 miles north-northeast of the Massachusetts state boundary, in Whitingham township. We considered the igneous origin for these beds, but found no sufficient criteria for settling the point that way. Some Massa-

[1] Emerson, B. K., Mon. 29, U. S. G. S., p. 68.
[2] Dale, T. N., Bull. 597, U. S. G. S., p. 41.
[3] Emerson, B. K., Mon. 29, U. S. G. S., p. 76.
[4] Loc. cit., p. 78.
[5] Emerson, B. K., Bull. 597, U. S. G. S., p. 41.

chusetts workers have suggested that these beds were "ferruginous or perhaps tufaceous deposits without the influence of granite." We preferred to call them dioritic dikes at first, but have come back so far as our Vermont evidence is concerned to the sedimentary origin. We have found no emery nor serpentine nor rock from which serpentine might readily be derived, hence in our area have no need to explain by igneous intrusion nor by tufaceous surface eruptions. We, therefore, included the whole section eastward to the chlorite schist all in the Readsboro, and see in it considerable variation in the character of the sedimentation, but no igneous activity. This, of course, throws out no barriers to the igneous interpretation for the extensive, interesting and valuable emery and serpentine bodies in Massachusetts. They may indeed well be considered basic intrusions in the Readsboro or its equivalent (in part) the Rowe—intrusions not extending into Vermont in these horizons.

We have several kinds of hornblende schist in the eastern part of our Readsboro. Some beds are mostly feldspar and hornblende and these tempted us most to use the igneous origin for them; some are sericite, hornblende and quartz with the hornblende scattered in bars or bunched in pretty rosettes. These we were sure were of sedimentary origin.

The Halifax Equivalent.—By placing the maps together again we find our Halifax matched up so far as we have worked it with the Savoy schist of the Massachusetts map. There is no break in our succession and none in the Massachusetts section, hence structurally the two units seem also to be equivalent. But mineralogically according to our descriptions and those of Emerson they are very dissimilar. It seems probable that we have not done enough work in the narrow wedge we have called Halifax schist. It was the last formation reached, it was not crossed completely, in enough places to know its upper limits, and owing to the fact that weeks, not area, limited our operations we did not master this formation. May we, therefore, be permitted to drop the correlation here and take it up at this point at a later date?

We found no means in our area of ascertaining the age of any of our formations. No fossils with the exception of certain structures of possible organic origin in the Sherman marble at Sherman were found. Our succession of rocks is short and conformable throughout so far as we could find. We have shown the probable equivalency with the Massachusetts series and Professor Emerson ascribes all the formations with which we have correlated, to the Ordovician. There seems to be no reason to question this decision. Therefore, we will consider our whole section as belonging to the Ordovician system. There seems to be good reason for considering it to be the larger part too of the Ordovician as exhibited in southern Vermont.

IGNEOUS ROCKS.

General.—Igneous rocks are only in small dikes and stringers in this area. No lava flows, surface eruptions or even tufa deposits were recognized. However, igneous rocks are widespread both in time and space and intruded into every formation. Further they vary considerably in character and are so interrelated that their relative ages are perfectly clear.

There are four distinct types of rocks grouped into two divisions as follows:

- Basic dikes.
  - Biotite dikes.
  - Diorite dikes.
- Acid dikes.
  - Granite Dikes.
  - Quartz and quartz-feldspar dikes and stringers.

Biotite Dikes.—This material was first seen a mile and a half northeast of Wilmington in the hills on the east side of North Branch Deerfield River. At this point it was almost pure biotite. This occurrence not being in the area now before us, similar occurrences farther south will be noted.

Dikes of this type were found at S-20, V-31, M-21, L-25, Q-15, D-31, q-21, q-27, e-9, and e-18. These are all in the Readsboro, with the exception of D-31, which is in Heartwellville. They are so dark that they would be difficult to discover, in either the Heartwellville or the Halifax. They may occur as frequently in both, but were not recognized if they do. While dark to black biotite is the dominant mineral in every occurrence, quartz (5 to 10 percent) is present, and at e-18 constitutes 15 to 20 percent. Quartz is always clear to slightly milky. Feldspar makes up 1 to 2 percent of the rock, and calcite was found abundantly at Q-15, and in small quantities at V-31 and S-20. No magnetite was found except at Q-15, although every specimen taken was crushed and tested. Pyrite was found at S-20 both fresh and limonitic. Limonite was found in most places and is reckoned as secondary by oxidation of pyrite. No other mineral of the Readsboro or Heartwellville was recognized in this rock.

Variations from place to place were slight. Such differences in composition as suggested above were all that were noted. The rock is remarkably constant. It is always very dark in color, some localities show it a little more gray than others because of the larger percentage of quartz. Texture is even, fine, and distinctly schistose and foliated in every occurrence.

That the material is of igneous origin and not a local phase of the Readsboro is established by its relation to the latter. First, it is obvious, as will be shown later, that the Readsboro is of sedimentary origin. This fact was stated and maintained by the workers in Massachusetts years ago. Second, the biotite dikes interpenetrate the Readsboro in every direction in slender stringers and sheets, in bodies that thicken and thin as they pass from layer to layer, in lenses, and all connected up in any given area. Third, while never as thoroughly metamorphosed as the Readsboro, it always shows much schistosity and foliation, always coincident with that of the Readsboro. This point further suggests that the intrusions were made about the time of the metamorphism. If earlier then the metamorphism should be of the same order, if later, it should not be changed so thoroughly and need not have the same schistosity. No other igneous material in any part of our area shows any such degree of transformation.

The bodies of this rock are usually small, stringers are but fractions of an inch in thickness. Lenses and dikes proper are rarely more than a foot or two through. The thickest is probably at M-21, where the intrusion was traced for 200 to 300 feet with a thickness of 10 feet more or less. At S-20 nothing more than 6 or 7 inches thick was seen, although here is a rather extensive network of branching stringers, lenses and sills penetrating the Readsboro in every direction, both with reference to the compass and the bedding. At e-18 the mica dike is large and follows bedding of Readsboro remarkably well.

These dikes seem never to have mineralized the country rocks at all. No difference was ever noted along the contacts, but usually the boundaries were as sharp as could be expected after both rocks had been metamorphosed to schistosity.

There is no inclination on the part of any of us to consider any two of these occurrences connected, at least on the present surface. No statement can be made as to connections down below. Proximity and similarity of rock would certainly suggest probable unity of source for the materials.

Diorite Dikes.—Much more frequent are the dikes of diorite. They are widely scattered also over the area, are larger, and have given the impression of being much more connected into systems of dikes. Many occurrences are minute, so small that no attempt was made to map them, others are large and more or less continuous for hundreds of feet. Some dikes so far as we know are single, others are branching and even include blocks of the country rock. The diorite dikes, often called green dikes, are more frequently known in the Readsboro, but they occur in the Heartwellville in F-28 and in the Halifax at s-32. The dike here is described as very typical. It is associated with chlorite schist and the chlorite is a lens in typical Readsboro. These dark dikes are difficult to see in dark formations and probably were often passed unnoticed.

The largest occurrences found were about two miles north of Readsboro between the two roads. Plate XX. Many boulders were found on the fences and in the fields for a mile south of these rocks, pointing clearly to a large source near. While careful and repeated search failed to discover connections

between all the outcrops found in this vicinity, we believe if the drift and waste were removed much more continuity would be seen than the map shows. The main mass is probably 500 feet wide and is known at the east road in the garden, and about the fence in S-T-15. Continuous exposures were found westward up the hill almost to the west road through squares R-15 and Q-15. Large stringers lead off to the north from this mass and have been traced in that direction almost to the road. On the road in squares R-13, P-13 and O-12-13 the dike is known, but its absolute continuity could not be proven. On the south slope of the hill in O-12 it is known and at the center of M-N-11-12 is a large area of the rock. East from the main mass through squares T-15 and V-15-16 are outcrops and great boulders in abundance, but connections could not be found. At Y-15-16 above the west end of the big new dam, other extensive masses were found 400 to 500 feet across with both contacts against Readsboro exposed, yet no connection with other areas could be traced for, as usual, drift and other mantle cover the rock. Across the river southeastward and near the dam are many boulders and several unquestioned outcrops. Along the switchback railroad tracks good exposures can be seen of beds of diorite thrust into the Readsboro almost in a horizontal position. Some of these are very badly decayed, showing what weathering does for the rock. It is no wonder boulders do not occur far from their parent ledges if these exposures give a fair sample of the weathering of the diorite dike.

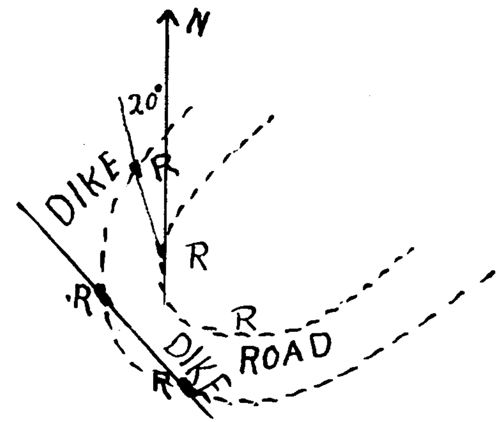


FIGURE 5. Diorite dike in Readsboro schist (R) near east end of big Whitingham dam (b-18). One side of dike trends N 20° W, other side N 45° W at places where seen. Exposures at thickened places on lines. Dike crosses road at the curve.

This dike could not be or was not traced over the hill eastward from the dam, but was found at e-19 and f-18 and again a half mile farther east at the fork in the roads, i-18-19. No patches farther east are known that might be connected, but if all these occurrences from M-10 to i-19 are parts of one great dike with several stringers, the total length is over three and one-half miles. There seems little doubt but this series of outcrops is one. No other such series in our area is known, but northeast of Wilmington a similar dike was actually traced over two miles.

Northwest of Whitingham, i-11-12, one and one-fourth to one and one-half miles extending north and south for about a half a mile, was found a green diorite dike of this same sort. This one has considerable interest because it is intersected and completely parted by a granite dike about 300 feet wide, thus establishing the relatively greater age of the diorite. Other scattered occurrences of diorite dike are known at K-25 and at K-29, J-34, O-17, P-Q-18, P-23, T-23-24, L-M-21-22, W-31-32, near the new large power plant, N-32, F-30, S-10, X-10, c-10, s-30, n-32, f-9, beginning almost at the water's edge in the large reservoir and leading in two stringers a long ways up the hill, and finally at t-u-27 and westward where a line of outcrop probably marks a continuous dike.

That these dikes seem essentially to be limited to the Readsboro does not prove anything save their greater visibility in that formation. Those at the surface in the Readsboro in the western part of the area have undoubtedly come up through the other formations studied and when the Readsboro shall have been eroded away over its present outcrop then the dikes will be at the surface in the older formations. And the dikes outcropping in the eastern part of the Readsboro no doubt came up into the Halifax, probably through it and have been eroded down with the Halifax to their present levels. There is no reason why they should not occur as freely in one formation as in another. They may occur more frequently in the central part of the great anticline, than out on its flanks or even in bordering synclines. The large dikes north of Readsboro might bear out this suggestion. It is true also that the large granite dikes to be described presently are near the axis. They too, however, must have come up through the other formations and now occur only in the Readsboro by an accident of time and stage of erosion.

Mineralogy of the Diorite Dikes.—In 1922 a paper on mineralization along the dikes of southern Vermont was prepared[1] as a minor study in our field work of 1920. Since this paper deals with exactly the same problems as those of the Readsboro region, free use will be made of it in the succeeding pages.

These authors point out that the diorite dikes are typically nearly 70 percent hornblende, with about 30 percent quartz and feldspar in varying proportions, and with pyrite or magnetite in small amounts. The range of ratio of the essential minerals is from 50-50 to 80-20 with every gradation between. The rock is generally fine, even grained, with the feldspar and quartz arranged in spheres or circles scattered more or less uniformly through the rock. In places these bunches are almost indiscernible without the petrographic microscope. In rare cases the centers of these lighter colored spheres are empty, but they generally contain biotite, magnetite and pyrite with limonite pseudomorphs after pyrite and very perfect hornblende crystals.

[1] Bray, Miss Harriet G. and Emery, Alden H., Ohio Jour. Sci., Vol. 23 (1923), pp. 83-88.

In a specimen where biotite occurred in the center of the sphere a microscopic study showed a zonal arrangement of the two minerals. The outer shell consisted of quartz with only microscopic crystals of biotite. The second had quartz and biotite both about equally developed and evenly intermingled and the center consisted of almost pure biotite in well formed crystals. The minerals occurring in the centers of the bunches also occur scattered throughout the diorite itself in ill-formed crystals. Even magnetite in the body of the rock rarely had regular octahedrons and perfectly triangular faces.

Three minerals are found freely along the borders of these dikes as a result of mineralization, others in traces. The commonest seem to be pyrite and magnetite, less frequently but much more attractive are the amphiboles, tremolite and actinolite. No doubt, too, the large crystals of biotite often found in the diorite have been influenced by the mineralizers. Pyrite is usually scattered through the dikes in single crystals along the border zone. Magnetite is scattered also, but frequently brought together in little aggregates of crystals and rarely in excellent large octahedrons with a brilliant iridescent tarnish. Pyrite is almost always in well formed cubes. Occasionally a large crystal of pyrite contains a smaller one of magnetite. Very often the pyrite is completely altered to a limonite pseudomorph and this before any other weathering begins.

Dikes occasionally contain small inclusions of the country rock, and less commonly dikes divide and flow around larger masses more or less completely. In inclusions hornblende and feldspar grow to larger size and more perfect shapes. Rarely fine small crystals of paragonite and phlogopite occur along the contacts.

The actinolite and less commonly tremolite make very attractive specimens at X-10; whole beds of the former show in the railroad cut along the borders of the dike. At e-19 along the new road around the arm of the big reservoir are quantities of actinolite, but no dike is known nearer than the next square, figure 5. Chlorite in very pretty crystals often accompanies the actinolite both near the dikes and along this road. It may be that these fine displays of these two minerals indicate the presence of a dike and its mineralizing powers, though the dike itself has not been found. If this be true we might be able to trace the dike across the hill from the east end of the dam by the actinolitization of the schist.

Nearly every diorite dike shows some mineralizing effects, either in its own body or borders, or in the country rock usually in all three places. In some cases the chloritization is the only evidence of the dike. In rare instances the dike seems to have done essentially nothing.

The dikes are often slightly metamorphosed. Perhaps half of them show no effects, but the other half show all gradations from the merest beginnings to a rather striking schistose structure. Yet they are not nearly so modified as are the black biotite dikes described above. They must be notably younger than the black dikes. The first evidence of the change is in the flattening of the white mineral spheres. Occasionally this seems to be only that flattening due to flow of the rock. In other places it is certainly a part of the regional metamorphism. All the minerals are banded, the quartz-feldspar bunches are drawn out into light lines an inch or more in length, the micas are all turned with long dimensions parallel to dike walls and the capacity of the diorite to split parallel to walls is marked.

The dike contacts are usually pretty clearly defined. This would always be true in Readsboro on account of the difference in color of dike and country rock if it were not for the mineralization. The best place to study contacts and really see the form of the dike was found at the turn in the auto road above the east end of the big dam and the Whitingham railroad station. Figure 5 shows the intersection of dike and road. Contacts here were essentially vertical and rather clearly marked. The sides of the dike are not parallel in the portion seen and drawn, but that may not mean that the dike is to run out soon toward the southeast, for these dikes are never uniform in width for any considerable distance. They widen out, then pinch up and then widen again.

The Granite Dikes.—While many of the so-called quartz dikes contain feldspar they are not to be confused with the granite dikes, for they are later and are known to cut across the granite. Therefore, they will be discussed separately.

The large granite dike was found on both sides of the river a mile or so above the site of the Davis Bridge. On the west side on the spur opposite the branch from Whitingham, is a small one, only a two-foot body. It was found close to the railroad along its new location. Another dike occurs at c-5-6 west of the reservoir and well up toward the north line of Whitingham township, while a fourth occurs at i-18-19 on the new road from Whitingham village around to the dam just as the new road leaves the old one that led to Davis Bridge. Up over the hill at h-i-9 are found a number of stringers of rather siliceous granite which look very much like the rest and no doubt are the same thing, although the feldspar is in smaller grains and possibly less abundant. All these occurrences are in Readsboro, but they must have come up through the formations below so occur in all formations.

The main dike runs W-N-W by E-S-E and is probably continuous beneath the deep water of the reservoir, for it was traced to the water's edge on both sides. It was followed far up into the hills westward in c-b-a-9-10 where it continually breaks up into stringers, first into two, then into scores, each becoming smaller until they are no longer traceable in the forest and beneath the mantle. Stringers cross beds of Readsboro and run along between them distinctly. East of the river there is a more unified mass from which stringers run out. The central dike with a width of 200 to 500 feet has been traced up from the river through a col between two hills in f-g-h-10-11 to i-12, where it was lost in a tamarack swamp. It has not been found on the east side of the marsh so we were probably near the end. Many branches extend out in varying lengths from this mass, and possibly some or all of the outliers noted as at h-i-9 and i-18-19 may be connected by stringers with this main dike, but we were unable to trace connections on account of drift, woods and other covers.

Mineral composition and texture show a marked similarity in all the localities. Milky to clear quartz makes up from 50 to 90 percent of the rock. It was taken for quartzite in some places until its relations were found. Feldspars occur in every place examined and out toward the central part of larger dikes as much as 50 percent. Crystals vary from very small to one-half inch across in most favorable parts, in good cleavable but not striated, milky to clear well formed shapes. It must have crystallized before the quartz. Magnetite is always present though never notable, it is in tiny splinters and distorted crystals as if not the first to form. Pyrite is rare, but rusty spots suggest a greater frequency in absolutely fresh material. Biotite is usually present though fine grained, and it is well shaped. Sericite is common along all weathered margins as if derived by weathering and probably from the feldspar.

Calcite is the variable mineral. Some samples gave no trace, others effervesced a little and briefly, while at c-14 calcite is present in large, well formed crystals in the midst of the dike, apparently filling seams or veins. This calcite is probably secondary and a product of weathering and leaching downward of calcite. In the central part of the larger dikes and stringers the texture is homogenous, but toward the borders and in the narrower dikes there is obvious banding. The micas are distinctly in layers. The sericite, developed from the feldspar by weathering, also shows banding as if there had been a flow structure in the rock by which the waters, responsible for the transformation had found a way into the rock.

The dikes do not greatly modify the country rock. They nowhere develop the rarer minerals as the quartz-feldspar dikes (see below) have done. But in many places the Readsboro is more siliceous near the contact as if siliceous juices had worked outward, stoping perhaps into the country rock a little and silicifying considerably whatever they entered. Larger and more regular quartz crystals occur along the borders.

The granite weathers less freely than the country rock and makes rather showy light colored exposures visible some distance across valleys because of their lighter color and lack of cover. The areas on the west side of the river by Camp Polly c-10 and those on the east side in g-h-i-11-12 are intervisible. Not only the outcrop, but many loose boulders weathering from the ledges help to make the hillside white.

It may be significant that these granite dikes only occur in the central part of the large anticlinal structure of our area. In doing work east and west of this area thorough search should be made for more of them to test the value of this observation.

The Quartz and Quartz-Feldspar Dikes.—This group of dikes is at once the most numerous, most recent, most widespread on our map, and has been the most active mineralogically. In scores of different localities these forms were noted, 12 to 15 new minerals are developed in and around them, they cut every formation and all other dikes, and are found in squares A to jj east and west, and 4 to 36 north and south. Our observations indicate that they are more frequent in the Readsboro or in the axial region of the largest structure of the region just as are the other dike types.

There are so many places where these dikes can be seen that an enumeration of them seems less valuable than for the earlier kinds of dikes. Most of them are so small that mapping them would greatly exaggerate their size, hence the locations will be given by types and only the more significant places will be mentioned. With the observed frequency of these dikes, and more than 80 percent of the rock covered by mantle, there must be literally hundreds of them. With such frequency they must be connected and intersecting more or less. In fact connections for many feet have been traced and intersections have been noted.

In composition these dikes vary from essentially pure quartz to quartz-feldspar combinations in which the feldspar greatly predominates. One could break sections across some dikes which would be almost pure pink feldspar in crystals one to two inches through.

The dikes vary in size from 10 to 12 feet in H-29-30 down to the thinnest threads. Thickness of one to six inches is very common and can be found almost anywhere Some of these have caused notable mineralization, others essentially none at all. It is probably true that mineralizing fluids were not of the same composition nor abundance in the different dikes, therefore, the results are different. There does not seem to be any relations between the intensity of mineralization and the size of the dike, nor again between the amount of change and the present composition of the dikes.

The large quartz dike mentioned above was traced nearly continuously for about 1,500 feet. The mass found at H-27 is probably a continuation of that at H-30. It has been locally known as the gold vein or the gold mine and there have been citizens willing to invest heavily in the mining of this dike for gold. For their encouragement it may be said that this dike, as well as many others in southern Vermont, has the same general aspect as the rich gold "quartz veins" of California, but like all others seen in southern Vermont it has one notable difference. While many of those in California have gold in them, these do *not* have gold in workable quantities. Some of them have pyrite, more have mica with shiny faces, both of which have been deceivers. In our opinion there is nothing in this vicinity that need to excite the cupidity nor elicit the shekels of anyone. There is very little mineralization aside from pyritization along this large dike. Scores of small ones have accomplished much more than it has.

At S-21 in typical Readsboro a dike of quartz and striated feldspar was found which had carried pyrite cubes from one-fourth to one-eighth inch across. These have oxidized to limonite pseudomorphs, and then mostly have weathered out, leaving the dike studded with rectangular pits. At R-23 and A-26-27 many small quartz dikes occur in the Readsboro. At D-25-27 quartz lenses and dikes occur freely, cutting the rock in all directions. All are thin stringer-like, some white or milky, some iron stained. The stain came from pyrite occurring in and near the quartz. In the country rock, Heartwellville schist, are many tourmaline crystals, some an inch long and as large as a needle, a few one-sixteenth inch in diameter, all are black, occurring singly, in bundles or in rosettes, but in the schist and not in the quartz. Garnets up to one-fourth inch diameter are also common here in the schist.

At the east end of the big dam b-18, quartz dikes cut the Readsboro frequently near the road. Near the dikes but clearly in the country rock are many garnets, which are more abundant along the bedding planes of the schist. No positive proof that the garnets were related to the dikes could be adduced, but it seems probable; and their abundance on the bedding planes then may mean that the mineralizing fluids could penetrate more freely there.

At L-21, in Heartwellville were found quartz lenses three to four inches thick and several feet broad. Along their margins the quartz had penetrated between the sericite folia and pried them apart, freezing and crystallizing there like ice and snow between old leaves. No feldspar or pyrite were detected in the dike or near, but garnets are frequent in the country rock, and in the interbedded folia of sericite. None were noted in the quartz. In one of the quartz dikes or lenses here, were multitudes of tourmaline crystals in radiating clusters. Single crystals two inches long and more than one-eighth inch through pierce the quartz in all directions. Others occur in the schist along the borders. The sericite of the schist seems to be considerably chloritized. No garnets at this place, but occasional felspars were scattered through the quartz. At D-16 is a dike of blue quartz in Heartwellville carrying pyrite and tourmaline.

At q-21, where a black mica dike was noted, quartz-feldspar dikes were also found, but with little mineralization except recrystallization of biotite. The quartz dikes cut across the older biotite dikes.

At u-32 quartz dikes have considerable well developed biotite in their borders as if their presence had assisted the growth of the mica. At w-32 in the green Halifax chlorite schist, quartz dikes seem to be responsible for the growth of actinolite in the country rock. At m-n-12 near the top of the hill, but on its east slope, occur small quartz dikes with much tourmaline in slender black crystals, and with large garnets in the country rock.

Quartz dikes are fairly frequent in the marble. At e-f-34 such a dike crosses the contact of marble and the Whitingham schist, producing much mineralization. The marble becomes coarse crystalline, with micas and actinolite. The dike has black tourmaline and the Whitingham schist has calcite, red and black tourmaline, and pyrite. Much of the tourmaline in the quartz is fine, granular, interbedded with the quartz, alternate layers being one-fourth to one-half inch thick. Gray and pink feldspar is present with the quartz.

The coarsest grained quartz-feldspar dike found in place was at v-21 in typical Readsboro. Pink feldspar crystals were two inches in diameter. No mineralization except recrystallization of some of the bordering mica was found. At R-27 in a pile of boulders gathered from the meadow around, were masses of similar coarse dike. Feldspar was abundant and in crystals one to three inches across. So little country rock was present that mineralization was not noted. This material was not in place where found, but could not have been far from its place of origin, but that place could not be located.

At j-k-18 the quartz dike is in typical Readsboro and has brought pyrite both in the dike and in the country rock.

Quartz dikes are found in the Halifax chlorite schist in a number of places, but they produce less change than in more siliceous rocks. Dikes are known at cc-33 and jj-25 and at y-23. In the latter place the chlorite and quartz-mica schists are closely

interbedded. The dike is made up of quartz and feldspar, of which the feldspar is much better crystallized. Large crystals of dark green chlorite have been formed along the borders of the dike, but beyond this recrystallization of the chlorite of the country rock, the dike seems to have caused little change. At dd-20 about a mile south of Jacksonville a dike of quartz and feldspar has been thrust into a dense, dark green, fine grained chlorite schist. The dike is more than 90 percent feldspar and the quartz is simply in stringers among the feldspars as if put in after the feldspar was all crystallized. All along the contacts the chlorite is recrystallized, coarse and harder than the country rock. Probably it is a new mineral. At w-32 a similar dike has developed both hornblende and the coarse dark green mica, from the chlorite schist. The quartz has seeped into the rock until the border line is quite indefinite, in fact a zone of feldspar, hornblende, quartz and mica. This rock is very handsome, but not abundant.

Quoting from the paper by Bray and Emery[1]: "The mineralization which results in some form of mica is by far the most common, and of the micas biotite is the most common form. Muscovite and hydrous green micas also occur. Biotite is present in good crystals along the contacts, extending into dikes and country rock. In the country rock it makes the rock look darker and denser along the contact. In one case some large beautiful crystals were found in the very center of a quartz dike. This phenomenon was probably caused by rapid cooling of the quartz which left cavities where the biotite crystals were formed and later were surrounded by an inflow of more quartz in heated aqueous solution.

"Muscovite is very rare. Phlogopite is as rare as in the diorite dikes, but paragonite is more common and occurs with muscovite in the schists in several places near the contacts. Inclusions of crystals of mica within the feldspar and the reverse are common.

"Epidote is not very common and generally occurs in rather massive form between the country rock and the dike. Large masses of actinolite, beautifully crystallized and associated with quartz are found in such quantities that it must be assumed here as perhaps for the epidote above that the largest part of the basic material for the mineral was already present in the country rock, and that the mineralizers merely changed its combinations, adding silica.

"Ilmenite occurs in medium amounts, almost always within the edges of the quartz dikes themselves, sometimes along the contact, rarely in the country rock. It is not usually in good crystals, but in plates as much as two inches long." A boulder

[1] Bray, Miss H. G. and Emery, A. H., Ohio Jour. Sci., Vol. 23 (1923), pp. 86-87.

found about a half mile north of Readsboro village and just south of quartz dike ledges has a lot of ilmenite in plates located just as quoted. The country rock carries 25 to 30 percent of small garnets and a similar amount of green hydromicas beside quartz, feldspar and biotite. Near the contact in places are fine bunches of slender, black tourmaline crystals, and pyrite was once present as shown by the limonite at present partly in pseudomorphs.

Continuing from the paper: "Magnetite is more common than ilmenite generally, but is usually disseminated through the country rock in imperfect crystals."

When the tunnel was put through the hill from the big dam to the power plant a quartz-feldspar dike was encountered and quite a quantity of the material was brought out and put on the dump. This material has a decided advantage over all other material collected in that it came from far below the surface and showed no effects of weathering. The exact location of the dike could not be learned, but since the hill is synclinal, and all Readsboro schist at the surface it is probable that the tunnel found nothing but Readsboro. This statement holds for the large hill north of the Readsboro-Whitingham road, but will not hold for the southern part of the tunnel. The material referred to came out of the adit at W-23.

The dike consists largely of milky quartz and feldspar, in part striated, in coarse crystals and varying proportions along its course. On the contacts are splendid sheaves of black tourmaline crystals, both in the quartz and the country rock. A coarse crystalline chlorite with a bright green color and very brilliant luster is also common in both. Pyrite and pyrrhotite are of frequent occurrence, possibly the latter the more common. It was carefully tested for nickel and copper with negative results. Garnets of good size, one-half inch diameter and under, are common in the bordering country rock. No ilmenite nor magnetite were detected. Several pieces rich in calcite were found, however. The cleavage blocks were mingled with the quartz, feldspar, and chlorite well within the dike. Some blocks were an inch across and gave no suggestion of having been made after the dike. In places the carbonate looked like siderite and gave a considerable iron reaction, but no magnesium, probably simply a ferrous calcite.

The above discussion of the dikes may be brought to a close with an expression often made during the field studies. This region just missed being an interesting mineral field and possibly a valuable ore area. The later dikes contain some oxides and more sulphides, but aside from the ilmenite and its titanium, nothing in a form to be of much economic value has been found. It seems probable that more mineralization may be found on a lower level only to be exposed after further uplift and another

PLATE XXIII.

From the top of the drift filling seen in Plate XXIV at an altitude of 200 feet above the river, looking north. Steepened slope on left is the youthful steepening in present cycle but done before glacial period. See drift in valley against this steep slope. Late Tertiary peneplain remnants in distance. River flows toward us from center of picture to the right around the drift fill. Rock pile on extreme right is the dump at the adit, fully 300 feet above the river.

erosion cycle or possibly deeper erosion in the present cycle. And with no traces of metallic minerals save sulphides of iron and oxides of iron and titanium and all these only in small quantities, it is no place to search, in the present stage of geologic development, for valuable ores of anything.

STRUCTURE.

Summary of the Data.—Not much need be added here concerning the structure in the area except to bring together all the data mentioned, and correlate them. There is one large north-south anticline, highest in the western part of the area in the broad outcrop of the Heartwellville. This is true even though the oldest rocks do not come to the surface for the Whitingham formation rises here to altitudes of about 2,300 feet, while it is only 1,900 feet where exposed in the Whitingham marble area.

This anticline is known to pitch sharply southward (figure 4.) Evidence is abundant in the southern part of our area, as well as in the northern part of Massachusetts as shown on Emerson's map. The strata dip southward and the lateral outcrops close around the southern end. It is believed to pitch northward also, although this fact is not shown in our area. In 1916 when we were working on the same structure around Wilmington we found strong north dips in the vicinity of West Dover; and the Readsboro-Halifax contact bears northward in Hogback and Higley and then swings around to the northwest. The rocks in Wardsboro and Somerset seem to be similar to those east of the Halifax formation. This point is not yet established. It needs much more work.

This anticline, 10 to 15 miles broad at least, has within its width several short pitching anticlines and synclines, like the one bringing up the marble in the Whitingham area, and those bringing up the older formations near Sherman, at camp, and in Readsboro. The axial fold is only one of these a little larger and higher. Most of the lesser anticlines are short and steeply pitching both north and south. Plate XXIII.

Then over the backs of these mile-to-two-miles wide anticlines are several small wrinkles. In the Whitingham marble area where they show to best advantage, more than a dozen are known in a width of 6,000 feet. The same wrinkled pattern holds over much of the area. It is well known all through the big Heartwellville area in the west, in the Readsboro area of Readsboro village and in Readsboro schist north and northeast of Whitingham village. It is known also in the Halifax schist, and one of the wrinkles in the row of hills east and northeast of Jacksonville running beyond our area, has probably been thrust-faulted along its crest and overturned beside. This schist yields readily to pressure, and develops wrinkles more than some do. Most of these wrinkles are probably less than two miles long, some much less than one, and they will probably not average more than 500 to 600 feet wide. They pitch at both ends and often pass at the ends into the opposite structure, anticlines here, synclines there. No area more than a mile square is known where these folds do not occur.

Beside these three sizes of structure there are two more, though it must be understood that there are no hard and fast lines between the grades or sizes of synclines and anticlines. The next two are smaller. The first may be said to be plications over the backs of the wrinkles. One can find scores of them in almost any area where the rocks are well exposed and reasonably fresh. Boulders over the hills or on the fences show them. There is a group of them on the lecture room table at Oberlin College. Its total length is about two feet, its width less than one. But in it are three folds; at one end an anticline on each side and a syncline in the middle all pitching, at the other end the anticlines both become synclines and the syncline becomes an anticline between them. This specimen came from a stone wall about a mile north of our line in Wilmington township.

The last structure may be called corrugations or crumplings and they occur all over many of these plications. The Readsboro shows them sparingly except in favored localities, but the Heartwellville is rich with them, and the Halifax is sometimes called the crumpled rock, or corrugated slate. These little crumplings are but a fraction of an inch high, *i. e.*, from crest to trough, and a larger fraction across from crest to crest, and they pitch or run out often in less than an inch. There may be finer foldings than these, but the microscope is necessary to see them.

Thus is will be seen that as a whole the dominant structure is the pitching fold, and this type is carried through the whole gamut of size from the large anticline 10 to 15 miles wide and 20 to 30 long to the tiny corrugations in the structure of a small hand specimen.

The problem set us in this area required very careful study of the cleavage, bedding, and jointing in their mutual relations before any reliable work could be done. When the same mass of rock seems to have two dips and two strikes either set of which is equally well developed, and capable of being taken for the true stratification dip one has to look carefully or give it up and search a new place. When new places may be hundreds of feet away, because of copious covering, that particular outcrop becomes critical and must be solved or lose the structure sought. The student finds ample opportunity to tune his wits in an area of this sort. Many of the cases in multiple examples so creditably set out by Dale[1] were found in our area. No need here to describe these structures farther, but the reader who expects to work such rocks is urged to familiarize himself with the thing in the field or with Dale's exposition before trusting his observations of dip and strike.

[1] Dale, T. N., Mon. 23, U. S. G. S., pp. 136-158.

GEOLOGIC HISTORY.

It is the purpose of a geologic history to set forth in chronologic order the events that have produced the results seen. Many of these events have been foreshadowed in the descriptive work already done. Some clew has been given to the order in several cases. It remains here to follow the processes through as they have carried on their work. So far as our area goes the processes involved are sedimentation, regional metamorphism, diastrophism, intrusion and contact metamorphism, erosion, and glaciation. These processes have not always operated alone, nor have they been satisfied with one period for some of them have recurred several times, and their times of operation have overlapped a great deal.

Sedimentary Record.—Since our formations are all conformable and probably all belong to one geologic period and since no observations are possible on older rocks or structures than those in our series, we may well begin with sedimentation. Although one must recognize that sedimentation must take place upon something, and that that something must have some structure, yet we cannot get at these things so must content ourselves with the items available in our area.

The five bedded formations, Sherman, Whitingham, Heartwellville, Readsboro, and Halifax are believed on several counts to be of sedimentary origin.

1. The quartz grains in many places show that they were once rounded and have been more or less completely restored by silica deposition.

2. The suggestion of bedding in so many places and especially the obvious crossbedding seen frequently in the Readsboro.

3. The calcareous beds at the bottom of the series, and the complete conformableness up through the series.

4. The lensy character of the materials in all the formations. Layers lens out in short distances and new ones come in, not like beds of lava nor of volcanic ash, but as if the materials had been washed into their places by active streams or currents. This seems wholly applicable to all but the marble, and with the wealth of mica in many parts of the calcareous rocks it would seem pertinent to apply it to the noncalcareous parts of these.

5. It has been pointed out by Bastin, as cited earlier, that chemical compositions show origins of rocks. The test has been applied to the Hoosac (Readsboro) schist with the result that the analyses show dominance of magnesium over calcium and of potassium over sodium, excess of alumina over the ratio of 1 : 1 necessary to satisfy the lime and alkalies, and a high silica

content. All four relationships point to a sedimentary origin for the formation. Analyses are not available for the Heartwellville and Halifax, but the mineral composition certainly looks as if three of the above tests would apply to each of these two formations.

We must take the position that these five formations are essentially of sedimentary origin. This does not mean that we believe no volcanic dust could possibly be among the materials, but that so far as the record in our area goes it was one essentially of continous water sedimentation. On this well established hypothesis the discussion of conditions will proceed.

There seems little possibility of getting back either to the conditions under which any one of these rocks were made or the compositions of the sediments from which they were derived, except through an interpretative study of the present rocks and the application of chemical, physical and geologic principles to the problems presented. It is obvious that the conditions varied greatly to bring forth such diverse rocks as we now have; that the sedimentary materials varied from time to time, not simply oscillated, but changed progressively from early Ordovician (Sherman) time, to late Ordovician (Halifax) time.

Conditions of Making the Sherman Marble.—This rock material was laid in waters that were alternately reasonably clear and quite muddy, at times even sandy, but on the whole the materials precipitated from solution greatly predominated over the sediments from suspension. Presumably the waters were not close to shore and not very shallow. There must have been enough of currents to bring in and shift about the clays which have been metamorphosed into the micas of today, and strong at times to bring in sands and strew them about. That there was life in the waters seems reasonably certain. Graphite is abundant in places, and in such associations is usually ascribed to the dynamic metamorphism of carbonaceous sediments. Its distribution does not suggest magmatic emanations, nor do the associated minerals. Therefore, its presence here is at least a strong argument for organisms in the waters. The limestone itself is also a bit of evidence that life was present, but it alone does not prove. In the exposures along the railroad at Sherman where the rock has weathered at least 40 years, there are structures standing out in weak relief above the rock surface, which look like the algal forms of unmetamorphosed limestones. These have been so changed that internal structures do not yield to our inquiries, but in general the thing looks in several places like an algal mass a foot or so across. Thus on three counts there is evidence that the waters contained life. Ordovician seas usually did as shown by the records in a multitude of other places. In fact our best evidence that these beds are Ordovician is based on the presence of fossils of Ordovician life in the same beds traced into areas of less metamorphism.

Slowly the calcium carbonate accumulated and at times clays and even sands with the carbonate. Everywhere the marble now contains dolomite. It may have been precipitated by organisms while the rock was being laid down or may have arrived later by dolomitizing fluids.[1] Whatever its source the magnesium arrived before the regional metamorphism that produced the tremolite, actinolite and tourmaline.

The sediments were feebly ferruginous, the iron probably being in the form of hydrates. Every sample of marble tested shows iron, but none has it abundantly. The accumulating sediments probably inclosed boron in traces which has been used subsequently to make the tourmaline. In some placcs the tourmaline is close to or within quartz dikes, but it occurs in many places where there is no sign of intrusion. When associated with intrusion it is never far from the contacts of the igneous bodies, hence here where it is widely disseminated, it may very properly be ascribed simply to the regional metamorphism of the sediments including their recrystallization. Intrusion is responsible for some of it and regional metamorphism for the rest. Tourmaline also has used some of the iron. The sediments probably contained iron enough also to combine with the sulphur of organic origin to make the pyrite.

There was some change in character of the sediments as the deposition went on. The organic matter became more completely oxidized, leaving less carbon for graphite, and the silica and magnesium for tremolite and actinolite became more common. Also the clays became much more abundant as attested by the larger percentage of mica in the marble of the upper strata today.

Conditions During Making of Whitingham Beds.—There is so marked a difference between the marble and the Whitingham schist that a considerable change in conditions seems probable. The change, however, was not to wholly new conditions and not wholly sudden. It consisted in a steady holding of the muddy, most clayey conditions, that occurred occasionally in Sherman seas, without the return of calcareous conditions, so that clays and sands greatly predominated in all layers and calcium carbonate was at a minimum in all. Further, this muddy, silty condition was very constant and uniform, hence the sediments were much alike all through the 40 to 100 feet. The sediments were more ferruginous and more sandy. Life was probably relatively much less significant in the formation of rock.

Inasmuch as the rock is so similar from top to bottom and spread all over the area signifying not only conditions, uniform through the Whitingham time, but also similar over considerable territory, it seems probable that the water was still deep, scores if not a few hundred feet in depth. As noted already, this forma-

[1] Clark, F. W., Data of Geochemistry, U. S. G. S., Bull. 616. This volume is heavily drawn upon in this discussion of the marble and also in that pertaining to each of the succeeding formations.

tion seems to correlate with the upper part of the Bellowspipe limestone of northern Massachusetts. On this fact follows the suggestion that the sources of the clays and sands were not southward, but probably northward. Therefore, shallower seas and the shoreline of Whitingham time lay northward or northwestward from our area.

No fossils were found and little to suggest the character of the life in Whitingham times. It may have been as abundant as in Sherman times, but it was probably not of kinds to secrete calcium carbonate so abundantly. Probably most of the forms enjoying clear waters migrated or perished when the muddy times came, and were succeeeded by those forms less fastidious, such as could live in muddy waters.

Changes Leading to the Heartwellville.—With a thickness of more than 1,000 feet it may be that Heartwellville represents a longer time than either the marble or the Whitingham, but we know such materials as went to make up this rock, sands and clays, accumulate more rapidly than calcareous sediments. Its thinning eastward and southward need not indicate less time, but greater distance from the sources of supply. If true, then the shorelines still lay to the north and northwest, and the hills whose disintegration furnished the waste may have occupied, in part at least, the present Adirondacks area. This does not preclude the possibililty of some waste having arrived from the east, but in our area we have not found any evidence of such sources.

The change in the character of the rock, found as one passes upward into the Heartwellville is not sudden nor marked, which means that geographic changes, and the differences in kind and rate of sedimentation were not great, but in the course of a few feet the transition is complete in the rock from a biotite-quartz schist to a sericite-quartz schist. Therefore, there was such a change in the kind of sediments as might be responsible for the change in the mineral composition mentioned.

Students of metamorphic geology believe very little change in the elements and the relative proportions of the elements occurs during the metamorphism of sediments into schists. The chief differences between biotite and sericite are the presence in biotite of Mg_2 (Fe) with Al_2; and in sericite of no Mg_2 (Fe) but Al_3. It would seem then that the differences in the sediments must be essentially more magnesium and iron in some available form, and a little less of aluminum. Since kaolin, the basis of the clays, has Al and Si in the same ratio as does sericite, normal kaolin might be expected as the foundation for the sericite in the Heartwellville. Since quartz grains would probably be less efficient, less active, in the metamorphic mineral transformations than colloidal silica or hydrate of silica, it may be true that the quartz sand constituent remains about the same in the two rocks, but that in the sediments of the Whitingham there was more hydrate of silica and less of kaolin. Thus on the arrival of the conditions of pressure, temperature and other factors competent of metamorphose, the sediments, those to become Whitingham consisted of quartz grains, magnesium carbonate or hydrate or possibly hydrous silicate, iron hydrates, and some kaolin with free hydrate of silica; while at the same time, those to become Heartwellville contained quartz grains, very little magnesium compounds, only enough iron to be worked into the garnets and tourmaline, and little or no hydrate of silica. These substances may be grouped into two categories, the quartz in one and the rest in another. The two categories varied in proportions from place to place and time to time. There were times for example when almost clear sand was laid and other times when the second group was nearly free from sand admixtures. This variation of ratio may account for the variations in the mineral composition of the schist from highly siliceous to highly micaceous types.

The boron of the tourmaline and the potassium of the micas is believed to have been present in the sediments, for the simple reason that the minerals containing them, tourmaline and sericite, are so uniformly distributed, even in places where dikes occur, that it would be difficult for mineralizers to bring about their present distribution. Moreover, these minerals are just about as frequent far from dikes as near. Analyses of rock tourmalinized by contact metamorphism show no tourmaline or boron more than a few feet from the contact, and show also a sharp diminution in percents of boron and tourmaline as the distance from the contact increases. We are thus inclined to the conclusion that the tourmaline and, of course, the sericite and garnets were developed by regional metamorphism of sediments containing essentially all the ingredients used to make the several minerals.

The only changes in the sediments during Heartwellville time seem to have been oscillations in the ratios of sand and clay ingredients. Calcium carbonate is rare in the formation, graphite has been found but two or three times and all fossil impressions in the initial shales would have been obliterated by the metamorphism, hence we have essentially no record of Heartwellville life. No doubt something lived in the sea at this time, but its record is very meagre.

Readsboro Conditions.—The contact between the Readsboro and the Heartwellville is usually rather sharp, but shows no evidence of erosion. Deposition of sediments was apparently not broken, but the character of the sediments was changed.

Since there is so little calcite in the Readsboro schist it seems probable that lime-secreting organisms were rare and that very little calcium carbonate was precipitated with the sediments. Quartz sand was the most abundant of materials dropped into the seas during this epoch. Clays probably come next, clays consisting largely of kaolin, but since the dominant mica is biotite in the schist there probably were hydrates of iron and silica and possibly hydrous magnesium silicate as talc or serpentine. It is hardly probable that the magnesium came down as carbonate, for carbonate even now is very scarce in the Readsboro.

In the Readsboro tourmaline is very rare except along dikes, hence it may be inferred that the sediments were essentially free from boron, but the micas pretty generally contain potassium, hence it is inferred that potassium was widely distributed, but never abundant in the sediments. It may have been entrapped as potassium aluminate or silicate, and in the metamorphism, kaolin and one or both of these compounds may have been linked up together with dehydration and recrystallization forming mica.

Because the proportions of quartz and micas vary so much up through the formation, it is a reasonable supposition that the ratio of sand to clay in the deposition varied. This variation is more frequent and more marked than that in the Heartwellville. It is such a variation as should be associated with shifting currents, often vigorous ones. In fact it looks as if such succession of sediments could best be interpreted as of delta origin, hence relatively near shore and in shallow waters. Frequent cross-bedding in the Readsboro supports this interpretation. Cross-bedding is still more frequent and often very striking in the same formation in Wilmington township to the north. On the assumption that the shoreline and the sources of sediments are still lying off to the northwest it might be safe to infer that the sedimentation had gone on so far since change of level that the shoreline was building out into the sea and hence new lands were encroaching upon the waters just as any deltas, Po or Mississippi for example, are doing today. And following this interpretation, the explanation of the Rowe and Chester formations comes naturally. Emerson in his geology of Massachusetts expresses his conviction that the Rowe is thinning northward considerably and the Chester to some extent. Our work, as already shown, gives these two formations much less of thickness than is ascribed to them in Massachusetts and we find them so like the Readsboro that we do not map them separately. Thus what seems probable is that during the time of making, the Hoosac and such part of the Readsboro as is equivalent, the level of the sea rose less than the aggrading, so that at the end of that time the sea was about full out from the shoreline southeastward to the Massachusetts-Vermont line. Then very little deposition occurred in our area, just enough to level up to sea-level, while larger quantities of sand and clay were carried beyond and laid in northern Massachusetts. This would make the deposits thick in Massachusetts for Rowe and Chester times and very thin in our area. They would be different too from those below. There probably then followed the oscillation of conditions resulting in the interbedding of Readsboro and Halifax. Such oscillations could be brought about by intermittent depression of the sea floor alternating with active aggradation. The sand-free (or nearly free) muds of Halifax-like rocks were laid then when waters were deeper, and the beds with more sand when the aggrading had shoaled the waters. Then the next Halifax-like beds would follow another small submergence and finally, by more submergence, proper depth and other conditions obtained to make the beds for the Halifax formation.

We find evidence of an unconformity just beyond where we have mapped, cutting, in the present topography N-N-E—S-S-W from a point a mile east of West Halifax village to a point three to four miles south of the village. This is also reported in Massachusetts by Emerson. Nothing more need be said of it here, for it was beyond our area, except to suggest that it means an uplift which closed the series of Ordovician rocks with which we have been dealing, probably long before Ordovician time really closed.

Returning to the Readsboro sedimentation briefly, something should be said of the bedding and of the feldspar content. In the lower part the bedding is often quite even and the rock splits into excellent slabs. These even-bedded layers are not local, but can be traced several miles. In fact it seems probable that fine, split-rock occurring north of Wilmington is in the same horizon as that found around Readsboro and northward. Such even bedding over distances of 10 to 12 miles seems to mean very early stages of delta building when the waters were deeper, so that similar conditions prevailed widely, when waves and sea currents laid the sands and not river distributaries. We have wondered how much cross-bedding and the cut-and-fill process have had to do with the confusion of bedding and foliation. It would seem that in such a place as this was, foliation or schistosity might be more persistent in direction than delta-bedding, and if developed with the bedding in one place would have to be at an angle with it near by, unless its direction changed as frequently, and in the same way as the direction of the bedding. We could do nothing with this problem this past summer, but have left it in the hope that some future time may avail to work it out.

In regard to the feldspar in this formation, two interpretations are possible from a purely empirical viewpoint. First, that the feldspar was eroded from the lands and laid in small grains with the sand and hence is primary with reference to the sediments, *i. e.*, that it has always been feldspar ever since it was laid down. Second, that kaolin and other ingredients of the sediments have been combined to make the feldspar, hence that it was made by metamorphism after the sediments were laid.

The first interpretation seems difficult to apply here. If the rocks being destroyed to make the sediments of our formations were so far disintegrated as to make clays and hydrates, it seems hardly possible that so much feldspar could have escaped during all the weathering and transportation. The more improbable does this seem when one recalls that feldspars are quite unstable in the air, for they are attacked by water alone, by water containing carbonic acid gas, and by acid as well as by alkaline waters.[1]

By the second interpretation the only difficult part of the problem is to find enough potassium and sodium to make the feldspars. It seems probable that a plenty of these elements could be caught by the sediments as they fell through the waters and carried down with them, providing the waters were marine. We have no reason to question the supposition that these sediments were laid in salt waters in an arm of the sea with possibly open connections at both the north and south ends of a broad strait or trough, hence essentially salt water throughout. This general geographic distribution of land and water seems to be well confirmed by abundant findings in New England and bordering lands.

Our interpretation then for the presence of the feldspars in the Readsboro is that sufficient kaolin was laid with the sands in these delta beds to form the basis for them as well as for the micas, and that from the marine waters sufficient sodium and potassium salts were also incorporated, that when the metamorphism came the clays were dehydrated and the sodium and potassium combined with the aluminum silicate and built up the feldspars with the other new minerals. There is nothing in such an interpretation to do violence to our knowledge of the generation of feldspars. It is but a step further than the making of muscovite and sericite. This step has been taken artificially by C. and G. Friedel[2] when they succeeded in preparing orthoclase by heating together potassium silicate, muscovite and water at a temperature of 500° C. By use of a longer time than is possible in a laboratory experiment, and the pressure of thick superincumbent rocks, this process might be successful at a somewhat lower temperature.

The Conditions Obtaining During the Making of the Halifax Chlorite Schist.—The schist is made up of a large percent (75 to 90) of chlorite and a small percent of quartz (5 to 20) with various accessories as hornblende, actinolite, garnets, sericite and other micas and, rarely, feldspars. The deposits from which this group of minerals could best be made would have first a small percent of sand and a large percent of kaolin. These two products of the decay of crystalline rocks would be rather constant. In addition for any of the commoner chlorites,[3] magnesium and iron must be present. These no doubt would be in the form of hydrous

[1] Clark, F. W., Data of Geochemistry, U. S. G. S., Bull. 616, p. 367.
[2] Friedel, C. and G., Compt. Rend., Vol. 110, 1890, p. 1170.
[3] We do not know what chlorites are present, but we believe prochlorite and clinochlore greatly predominate.

silicates or hydrates and more than likely largely colloidal. Inasmuch as, in the hydromicas, the ratio of alumina and silica is not 1 : 1 as in kaolin, there should be an excess of the one lacking in each case either as a hydrate or a soluble oxide, and preferably for ready reaction, in colloidal form. For example, if a mica with a ratio of alumina to silica of 2 : 3 is to be made there must be in addition to the kaolin a considerable amount of other available silica to enter into the new mineral; on the other hand, if the new mica is to have a ratio of 14 : 13 or 8 : 6 there must be present sufficient available alumina to make up the deficiency in kaolin. Probably in the clays of this formation there were present, generally, excesses of silica. The actual reactions are not as simple as this statement would seem, for probably most of the micas are mixtures (isomorphous or not) of several more elementary compounds in varying proportions.

The hornblende is usually in small quantities and is actually usually limited to a few thin horizons. It contains more calcium and less magnesium than the chlorites, hence the beds from which it is derived might well vary in composition so as to have calcite or calcium compounds competent to enter the reactions producing hornblende. Experiment[1] has produced hornblende in three months by heating under moderate pressures, and with temperatures of about 550° C., hydrate of silica, alumina and the hydrates of magnesium, calcium, ferrous and ferric iron. These substances are all possible in clays, with kaolin as a basis besides.

Garnets are easily formed in shales with ferrous iron. The pressure under the strata laid later is sufficient and the temperature need not be high when acting through long periods of time.

Thus it seems, for all the present schists in the area, varying sediments are competent under regional metamorphic conditions to produce the rocks found today. Probably in every case the sediments are the products of thorough hydration, oxidation, and comminution, hence long weathering, transportation and sorting with final precipitation are necessary to produce them.

The sedimentary record described in the last few pages did not stop with the making of the rocks described. These rocks now at the surface are profoundly metamorphosed. Pressure, and temperatures of several hundred degrees have been necessary to effect the changes. Sufficient pressure and heat could not be applied at the surface, hence we assert that hundreds, possibly a few thousands of feet of sediments more were laid than are preserved to the present day. Further evidence of these other sediments is found in the igneous material now at the surface. It could not be in its present form nor could it have accomplished the contact metamorphism seen with it, without temperature and pressure even more than is required for the regional metamorphism, hence again the thick cover of later sediments. Just when

[1] Chrustschoff, K., Compt. Rend., Vol. 112, p. 677.

the sedimentary record closed may not really be known. Silurian and later rocks are known very near east and south and they were probably laid over our area also.

Metamorphism, Folding and Intrusion.—Following the sedimentation came the pressure, heat and mashing, the folding, crumpling, plicating, and wrinkling, the shearing, jointing and probably faulting. There were four periods also of igneous intrusion. Most of these things have already been discussed in other connections. They must have proceeded periodically during much of the rest of Paleozoic time, culminating in Pennsylvanian or Permian time in the closing up of the Appalachian revolution. Some of the igneous activity, however, may have come considerably later. Their results are the metamorphism already thoroughly set before the reader, and the folding also minutely described. The metamorphic rocks and geologic structure resulting are already familiar.

Metamorphism and folding were not separate, but more or less synchronous. Much of the former has structures definitely related to the folds of the latter process. If the folding brought the rocks above sea-level, which seems almost inevitable, then there was erosion also during later Paleozoic time.

The folding and other processes mentioned in the previous paragraph affected so much, not only of our area, but of that on all sides of us, and affected all of it so similarly that it is called regional metamorphism. Some of the general, regional metamorphism had been accomplished before the intrusions began as is shown by the fact that the oldest intruded material is less altered than the country rock. The black biotite intruded material has wherever seen been modified some. It is schistose in every locality seen, but it certainly has suffered less than the rock surrounding it. Moreover it is in the country rock usually along the plains of schistosity rather than along bedding planes.

These facts do not date the folding nor the metamorphism nor the igneous intrusions, but they do correlate them. There is no doubt that the folding and metamorphism were synchronous, and probably as little question that both occurred in Paleozoic time. Consequently the earliest intrusions were Paleozoic. Inasmuch as the earliest intrusions were involved in some of the metamorphism they must have come before that process ceased, hence in Paleozoic time too. Again the second intrusion, that of the dark, diorite dikes also occurred before the metamorphism ceased, for many of these dikes show some schistosity and other evidences of the metamorphic processes. For two reasons we believe the diorite was intruded long after the biotite dikes. First, it cuts across the biotite dikes. Second, if the relative degree of modification may be taken as a guide the second dikes were put in place a long time after the first, for many of them show absolutely no effects of the metamorphic agencies. But since some

of them do show some effects it is reasonable to date the diorite dikes near the close of the metamorphism or probably late Paleozoic.

The granite dikes show no effects of the mashing, folding, crushing and schistosity so obvious in the older rocks, hence we infer that they came into their places considerably later, too late in fact to be involved in the regional metamorphism. They are responsible for a little mineralization along their contacts, change which is superimposed upon the regional changes. Thus the order of events becomes thoroughly established. And with this order we must assign the granite intrusion to post-Paleozoic time providing our dates for the regional metamorphism closed with the Paleozoic. We would be willing to date the granite later than the Triassic, leaving the Triassic for the basic intrusions of the Connecticut valley alone. It might be unreasonable to place basic and acid intrusions in the same time and so close together. We have no evidence that they are, or are not, related. The granites may have preceded the Triassic trap so far as our studies are concerned.

There must have been much erosion in the region by the time the granites were intruded, but this erosion had not reduced the land nearly to the present surface, for even the intrusion of the quartz and quartz-feldspar dikes came at least to the present surface and they crystallized there too, in excellent form, hence must have been sufficiently covered to have cooled slowly under pressure. And we may be sure too that these dikes came after the granite intrusions, because they cut across the granite as across the country rock.

Not only are these quartz-feldspar dikes coarse crystalline, everywhere, even coarser than the granite and much coarser than the diorite, but also they have produced a lot of mineralization or contact metamorphism. This work could not have been accomplished without heat, hence cover and pressure. The actual mineralization has been fully described on previous pages. Its date is all that needs discussion here. With reasonable certainty then we may say these dikes were here before the later cycles of erosion, which wore the land down to the present surfaces, but they came well after the granite intrusions, hence still longer after the regional metamorphism ceased. While actual dates cannot be established for the quartz-feldspar dikes it would seem reasonable to consider them as belonging to late Mesozoic time. It is entirely possible that connections outside our area may be, or have been, established that will locate them chronologically, both differently and more securely than we can. We know of no evidence that will do more than we have done above and we realize that these actual datings are little more than conjectures. We are open to suggestion, evidence, and conviction from external sources. All we are sure of here is the chronologic order of the events.

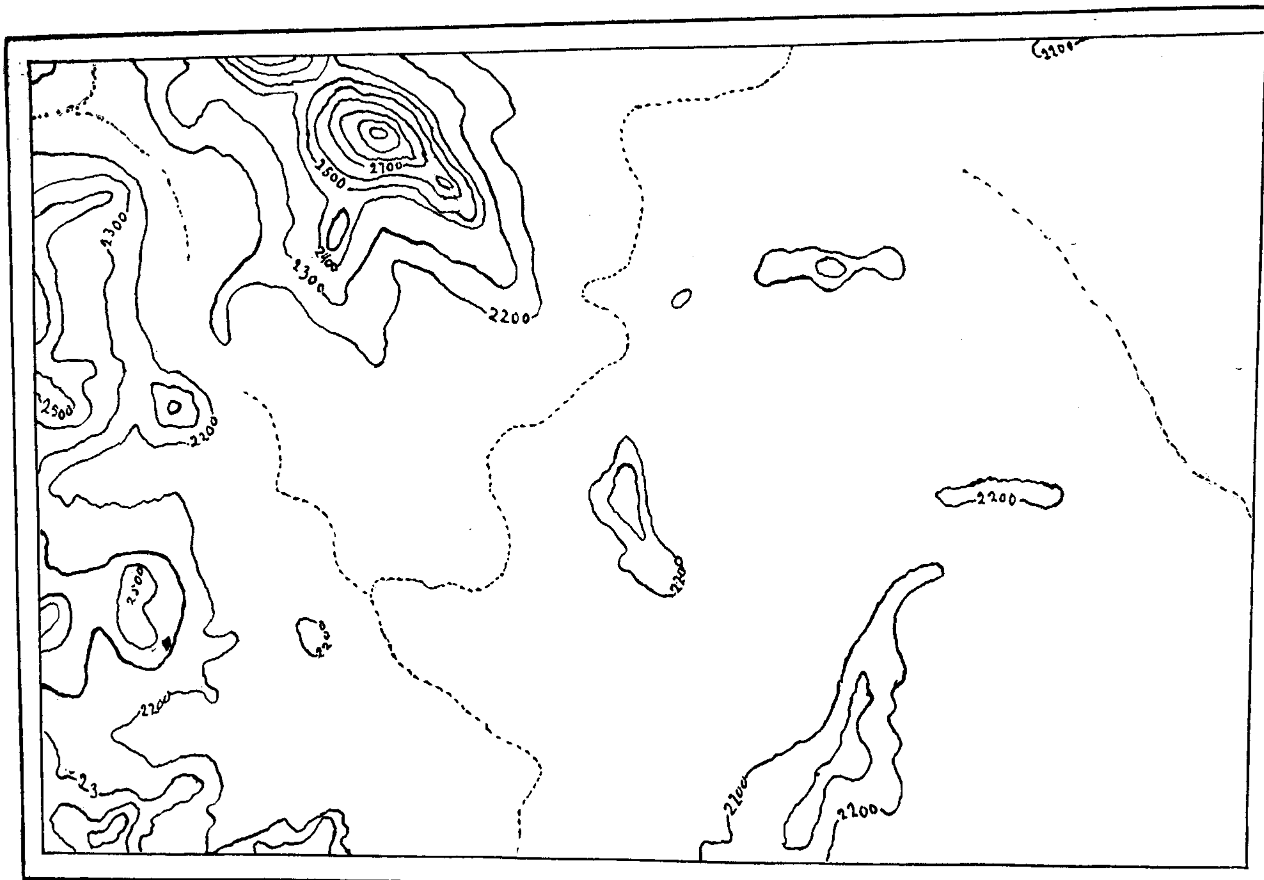


FIGURE 6. Contour map to represent roughly what the country would have been like at end of first recorded erosion cycle, if elevated to present level but without any dissection. Broad, nearly level areas with a few monadnocks rising 200 to 800 feet above the valley floors. The map may also be thought of as showing the topography if the present forms should be filled in to where they were when the second cycle began.

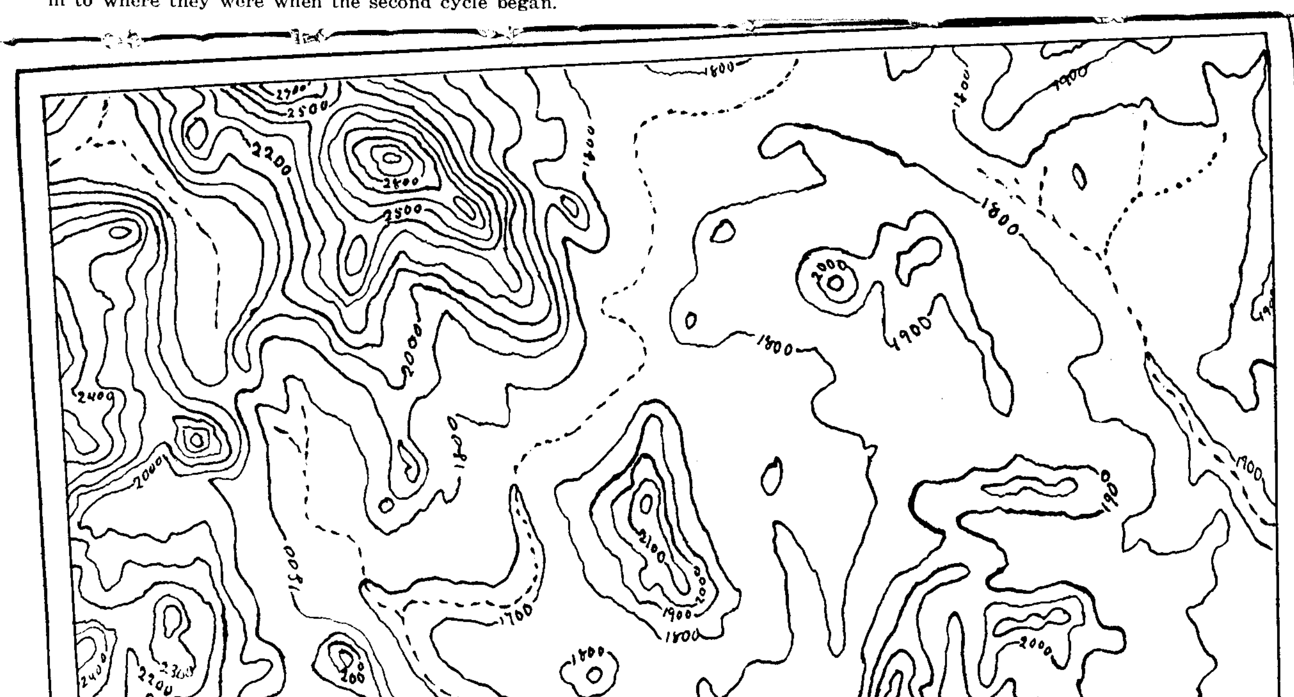


FIGURE 7. Contour map to represent roughly what the country would have looked like at end of second recorded erosion cycle if elevated to present levels. Broad mature valleys have been carved in the valley plains of Fig. 15. Some monadnocks still show but they are 400 to 500 feet higher above this second plain than they were above the first. Present streams have already carved trenches in floors of valleys of this second stage. This map may be thought of as representing the appearance of the present country if it should be filled in as it was at the end of the second described peneplanation.

Our area seems pretty positive on this matter so far as we have outlined it above.

Erosion and Erosion Cycles.—In the Outline of Topographic History, a section in the Introduction, mention was made of extensive erosion, and even of several erosion cycles, and of glaciation followed by post-glacial erosion. In that section, however, the evidence for these things was not discussed nor even presented.

That there has been profound erosion in the region is established by two independent lines of evidence, one of which has been suggested in discussing metamorphism. First, the rocks now at the surface or just below the mantle rock are everywhere crystalline. They are nowhere such rocks as can be made at the surface. Where igneous they are crystallized, not glassy or stony; dense and solid, not scoriaceous and vesicular; coherent not loose, ash-like. Thus their character indicates that they were not made at or near the surface where now found, but under deep cover where pressure kept them dense, preventing the gases from expanding and giving them a porous texture. Their crystalline character stands for heat through a long period of time, long enough and hot enough for the several generations of crystals to form, hundreds of years at least of very slow cooling from temperatures sufficient to make the rock flow. Cover again is necessary to keep this heat in for the centuries of slow crystallization. Just how many hundreds of feet of cover are necessary cannot be said, but it is certainly quite apparent that no valleys could then have been carved down nearly to what is now the surface rock. There must have been thick cover, hundreds, possibly thousands of feet of rock continuous over the country above what is now the surface. This does not mean necessarily that the land was then thousands of feet higher above sea-level. The rocks constituting the present surface may have been below sea-level, even hundreds of feet when the intrusions were made. Now if these intrusions were made into country rock and crystallized there when the rock was deeply covered, and if the intrusions are now at the surface, deep erosion must have occurred to remove the cover.

Further, the country rocks to the top of the highest hills and mountains in the area, and even in the Haystack and Greylock ranges respectively on our north and south, are metamorphics. These higher summits in our area are about 3,000 feet and in Greylock and the Haystack range over 500 feet higher. The metamorphism shows no signs of being less at the summits than elsewhere. All these metamorphics are such as can be made only under great cover and pressure, and the cover was essentially as effective over what is now the tops of mountains as over what is now valley bottoms, 2,000 to 3,000 feet lower down. Hence the cover must have been so thick that an additional 2,000 feet made little difference. One surely is safe in assuming a thickness of at least a mile covering these mountain tops, possibly more.

Another item in the rocks that testifies to the presence of former thick cover is the folding. The intensity of crumpling, plicating, wrinkling and grand folding has been fully described. Such folding and plication could not be carried on without heavy cover else the rocks would break and not bend. Further, the large folds if restored would carry the layers very much higher up. We have seen the large anticlinal structure running north and south across our area with the oldest rocks cropping out in the axis west of Readsboro and Readsboro Falls at altitudes of 2,400 feet. The Readsboro formation with a thickness of 4,000 to 6,000 feet outcrops on both flanks and around the south end as if it once had gone entirely over the anticline. Possibly the Halifax went over too though the evidence is not as clear, and if it did go over probably not with the same thickness now holding in the Halifax region. This matter of structure has been set out fully enough to make it clear that at least 5,000 feet of material has been eroded from our high parts in the west, and similarly large thicknesses in the central part. The same folded, plicated structure continues to the east and probably a similar amount of cover once lay over it. Hence extensive erosion is established for the whole area, on the grounds of rock texture and structure.

The second line of evidence is in the erosion forms themselves. It was stated in the Outline of Topographic History and described farther under Topography that the most mature topography is well up in the hills. If one climb to altitudes of 2,300 to 2,400 feet in the western part of the area where he can look out east and south, he will be impressed with the number of places and amount of area about at his level. He will see little evidence of the great valleys carved hundreds of feet below that general level, in which active streams run, and busy roads and towns nestle. Land from 2,000 feet up to his level or a little above, will seem to dominate the country and he will see a few broad rounded summits rising above this level. Such a general level, while not nearly a level surface or a plain, is called a peneplain or "almost a plain" and is known to represent an ultimate stage in subaerial denudation. Streams starting above this level have carved valleys, gorges first, down to this level; then they have widened out the valleys, and through the centuries, by lateral planation and headward erosion they have succeeded in wearing away nearly every thing above this level The only remnants left above the peneplain are the well rounded hills such as the 3,024 foot hill about four miles north of Readsboro, and the rest of its range on north to Searsburg. These rose as hills 500 to 700 feet above the general level and there probably was no land lower than about the present 2,000 foot surfaces. Thus there was a total relief of probably not more than 1,000 feet, possibly not more than 700 to 800 and the steepest slopes were farthest back from the streams in these residual hills. Such hills are called today monadnocks after a very typical residual hill in New Hampshire called Mt. Monadnock.

Thus we have in these upper hills abundant evidence of long continued erosion, and deep enough to plane off all that was above this level. It is obvious that the streams could not develop a peneplain like this at an altitude of 2,300 feet above sea-level where it now is. It was probably developed at an altitude of not more than 200 to 400 feet if as close to the sea as it is today. This means, of course, that the highest hills of the area were probably not more than 1,000 feet high at that time. When that time was, is less easy to establish, but it is believed to have been in the early Tertiary. The peneplain then probably was finished after the last intrusions. It may have been begun earlier than the intrusions. There may have been, probably were, several cycles of erosion as complete as this, before this one began—cycles whose records were completely destroyed by the erosion of this cycle.

So the forms due to erosion, still preserved in the hills, as well as the textures and structures in the rocks help to demonstrate the profound erosion to which this region has been subjected.

The Second Peneplain Level.—If one climb the western hills only to the 1,800 or 1,900 foot level he will see even greater areas at this level or near it than he saw at the 2,300 foot level. More land will be above his level, and the areas distinctly below him or lower than 1,600 feet will be practically all out of sight. They are usually in such narrow valleys that their presence is scarcely realized when one is 200 to 300 feet above and back a short distance from them. The view presented suggests another peneplain, less complete (*i. e.*, less level and with larger and higher areas above it) than were seen in the higher view. If the observer be in the region around Whitingham or Jacksonville, however, this level looks even more like a peneplain than the higher one did in Readsboro township, for there are fewer, and only lower monadnocks here. Very few summits rise over 2,000 feet and these are broader and more advanced-mature than those above the higher peneplain, in Readsboro.

The interpretation is simple. The first described surface elevated to where its remnants are today may be represented roughly in figure 15. After the making of this peneplain described as averaging about 2,300 feet high, another uplift occurred. This uplift may be roughly measured by the vertical distance between the upper and lower peneplains, a distance which seems to be about 500 feet.

Such an uplift, of course, rejuvenated the streams and they began to deepen their valleys to the new level. As the centuries

went by they cut, first, gorges, down to the new base level, then wider valleys until the whole succession of steps of peneplanation were carried out as in the previous cycle. The process did not go quite as far as in the previous one, as is shown by the fact that quite a lot of the previous erosion surface is still preserved, but it went far enough to bring in advanced mature to old slopes over most of the area above what is now the 1,600 foot level in the eastern part and the 1,700 to 1,800 foot level in the western part. The general appearance of the surface at this time, with all remnants elevated to their present levels may be shown by figure 16. Its development seems to have been pushed far enough in the east, as was that of its predecessor, to essentially wipe out all larger monadnocks, but in the west like the earlier cycle it did not reduce all the monadnocks. This suggests that the Heartwellville and lower Readsboro may be a little more resistant than the upper Readsboro and the Halifax.

This cycle probably closed in later Tertiary time somewhere, as shown by what has occurred since. There was time, after it closed, for advanced youthful dissection of the peneplain before the glacial period, for the new valleys to be developed with reference to a new base level to depths 400 to 500 feet below the last. But there was not time for these valleys to be widened out into really mature forms, nor was there time for the streams to become graded to the new base level. Therefore, we shall assume that the second cycle discussed above closed in late Tertiary time, but not immediately prior to the glacial period.

With the closing of this cycle came the uplift which put the streams again at a new task, and the third cycle was started. As suggested in the above paragraph this third cycle did not go far until interrupted by the coming of the glaciers.

The wave of rejuvenation due to the last uplift is working up the rivers. Its effects and the limits of the uplift are much clearer in Massachusetts just south of our area than they are in our area. (See Hawley quadrangle.) The Deerfield is much more obviously entrenched in Monroe, Florida, Rowe, Charlemont, and Hawley townships than in our area. In these units the main stream is in a trench with a definite shoulder around the 1,800 foot line in the north, and the 1,600 foot line in the south, and its tributaries show the effects of the rejuvenation, reaching two miles up stream in Monroe township; four miles in Florida as on Cold River and its several feeder brooks; and five or six miles in Hawley and Buckland townships as shown on Chickley River and Clesson Brook and their small tributaries. The undissected upland remnants of the second peneplain are obvious everywhere above these more recent gorges.

This third cycle then had only gone far enough to work out these valleys in advanced youth before the glacial period was ushered in. The Deerfield had done the most to enlarge and deepen its valley, but its channel had not become graded by a large item. Down in Greenfield and vicinity the valley floors are 120 to 140 feet above sea-level and this is 100 miles from the sea. In the southern part of our area the stream bed is 1,020 feet above sea-level and only 20 miles in a bee line from Greenfield. This gives 900 feet fall in 20 miles, while the Connecticut has 120 feet in 100 miles. The Deerfield grade is over 37 times as steep. The stream-level of the Deerfield at the north side of our area is 1,430 feet. This gives 310 feet fall in 7 miles across our strip, a grade almost exactly the same as that for 20 miles below us or about 45 feet per mile. The Connecticut has a steep grade in this lower 100 miles compared with that of the Mississippi in its last 600 miles. It is thus easy to see that when the Deerfield shall have reached even such a grade as the Connecticut enjoys it will be much nearer sea-level in our area than at present. In fact, when it has a grade that shall be coordinated with the present grade of the Connecticut its channel floor will not be more than 200 feet above sea-level at Readsboro or 900 feet lower than at present. The Connecticut already has about such a grade as this, way above Brattleboro, or as far above Greenfield as is our area.

These figures have been given to show that the Deerfield is not nearly down to base-level in our area, that it has 900 feet at Readsboro and 1,200 feet at our northern boundary to cut before it reaches grade with reference to present sea-level. It probably will cut down most of this distance before it broadens its valley greatly, *i. e.*, before it goes far toward developing a peneplain in the present cycle. These figures too give some suggestion of the amount of uplift which has occurred since the close of the last cycle. Presumably the last peneplain, now at the 1,700 to 1,800 foot level, was made within 200 to 400 feet of sea-level. It has then been elevated about 1,400 feet in our area, whereas the first peneplain described was only raised about 500 before the second developed. Obviously the area is destined to become much rougher before it becomes smoother or leveler—much rougher indeed than it became in the previous cycle, because it is so much farther above sea-level. Summing these altitudes up in a tabular form they may be stated as follows:

3,000 feet	=	Summit levels of today.
700-800 feet	=	Relief at close of first cycle described, = height of monadnocks of the times above stream levels.
2,200-2,400 feet	=	Altitude today of oldest peneplain preserved; may be of early Tertiary age. Made 200-400 feet above sea-level.
500 feet	=	Amount of uplift of the oldest peneplain; second cycle began on this new lower base-level.
1,700-1,900 feet	=	Present altitude of second peneplain, made near sea-level, and elevated in late Tertiary time.
1,400 feet	=	Amount of uplift since completion of second peneplain—represents depth to which present streams may carve their valleys.
200-400 feet	=	Level down to which streams may cut in present cycle.
0 feet	=	Present sea-level.

This statement thus far does not deny the possible subdivision of either the 500 foot or the 1,400 foot uplift, into several uplifts, and consequently the times that their corresponding cycles represent, into several cycles. This probably will be quite possible nearer the coast. If there were more uplifts and cycles than we have found they should be found somewhat nearer the coast. We have been unable to identify more than two in our area in the time at our disposal.

Nor does this statement preclude the possibility of earlier cycles. We are sure there were earlier cycles—cycles whose records in forms are gone, but whose certainty is established by the great erosion that took place above our summit levels. A plane tangent to the higher monadnock summits from Haystack and Pisgah northwest of Wilmington, spreading to the south, southeast, and southwest, would descend seaward south and east, possibly it would descend westward. Such a plane might represent approximately an ancient peneplain whose making absolutely destroyed all previous erosion records. Even these summits must have been lowered by erosion, many feet in the cycles that have rolled by, so that at best they only approximately represent an erosion surface.

Returning to a further discussion of the third cycle initiated by the 1,400 foot uplift some time before the close of Tertiary time, it may be pointed out that its date is approximated by noting how much has been done, in the present cycle. Most of what has been accomplished was done before the glacial period. This is asserted on the ground that there is glacial drift in all the valleys of this cycle. Plate XXIII. In some places drift of two ages was found in them. It probably occurs in most places in the valleys unless removed by stream erosion after its deposition. Further, the form of the rock valleys has probably been but little modified by streams since the ice came on. Could we get out all the drift from the valleys we probably would have forms much as the streams had made them between the uplift and the first ice invasion. Hence we can speak of these valleys thus emptied as the work accomplished in a short, immediately preglacial cycle interrupted by the ice age.

In the rock forms then we have, with the exception of two items, essentially what the ice found when it came. First, all was mantled with residual rock waste. This mantle no doubt was deep except where the recently rejuvenated streams had carried it away. Second, the ice itself was the means of abrading and plucking, polishing and smoothening of many rock surfaces, thus modifying to a small degree the rock forms found. There were then when the ice came, the monadnocks of old rounded form rising above remnants of an old peneplain whose altitude was roughly 2,200 to 2,400 feet above sea-level. Plate XXV. There were below this fragmentary peneplain gentle slopes and larger remnants of a second peneplain much of which was 1,700 to 1,900 feet above sea-level. Then there were, below this level, principally along master streams, steep valley walls and youthful valleys down generally below present stream-levels. In these valleys were torrential streams as at present (figure 17), only then usually on the rocks. Their grades no doubt were nearly as steep as those of the present streams. They probably had no falls but may have had some rapids. They were rapidly deepening their valleys. No lakes adorned the scenery. It was probably wholly forested.

Glaciation and Its Effects.—In this chronological statement the coming of the continental glacier was the next event. This paper is no place for any discussion of causes or reasons for a glacial period because our area no more than any other holds the key to causes. But we do have abundant evidence in the area that the ice came, and came largely from the north, spreading deeply all over the area and far beyond. It overrode our highest hills with apparently about as much power as it had in the low places, possibly it had more, because less restricted. It had weight enough to hold its tools and carve the hilltops just as severely as any other part, therefore, we infer that the ice was so thick that a matter of 2,000 feet, or the measure of the rock relief, was an item of small moment in its thickness. If it were 4,000 to 5,000 feet thick over the hills, 6,000 to 7,000 feet in the valleys would not do much more work.

Old drift was identified in several places in the area, beneath new fresh drift, establishing the fact of at least two advances of the ice. Phenomena farther south, in and near New England, confirm our findings on this point much better than they could possibly be proven by our drift features.

A stream diversion in the northwest part of our area helps to date the ice advance. A study of the topography up the West Branch of Deerfield shows a sharp narrowing of the valley two miles and one mile below Heartwellville to a width much less than it is up the branch anywhere for four or five miles, or even up the small brook northeast of Heartwellville toward Searsburg. This last is all in the same kind of rock and cannot be explained on the rock-resistance basis. North Branch Hoosic River rises about a mile southwest of Heartwellville against a large drift

obstruction in the valley, and a tiny tributary of West Branch Deerfield also heads against this drift and flows north. The valley where this plug occurs is broad and mature as anywhere immediately above or below or for miles up West Branch Deerfield.

The probable interpretation here is that before the ice came, a stream heading up in the Camp and Beaver Meadows, and several other notches in the divide, flowed southeast to the present site of Heartwellville then southwest to North Adams; that two small streams from north, and southeast converged on Heartwellville, that during some stage in the ice advance or retreat, ice so lay as to obstruct this course between Heartwellville and Stamford, delivering considerable water eastward at Heartwellville. This water was forced to escape towards Readsboro and being laden with waste was able to saw down the col over which it had to flow and thus open up a good route from Heartwellville southeast. Whether the real col was just south or north of the present Readsboro Falls is immaterial to the interpretation. It seems more probable that the narrower notch south of the falls were the col.

So effective were these overflow waters that when the ice dam withdrew, the smaller obstruction consisting of drift southwest of Heartwellville was able to keep the stream to its glacial course and the diversion was complete.

A study of the notch near the falls makes it clear that the transgression was not first effected in Wisconsin glaciation. The slopes are too mature, the valley too wide and Wisconsin drift too abundant in the notch. If not Wisconsin then of course it must have been earlier. In comparison with other such notches whose dates have been worked out on independent local evidence, it seems certain that this notch has been maturing as long as all post-Illinoian time and possibly much longer; hence the diversion may well be ascribed to the advance of Illinoian ice or even be taken as evidence of earlier glaciation. The conclusion follows as a corollary that the ice spread into this region at the time of the diversion, from the west and northwest and not from the east.

The drift plug southwest of Heartwellville is out of our area and was not studied in detail. It is morainic in form, and hence was made at least in part during the withdrawal of the last ice, but there may be much more to say about it. There may be, for example, an Illinoian core in it overridden by Illinoian ice then by Wisconsin ice and later mantled by Wisconsin moraine forms. In any case it is a drift plug and the stream has been diverted probably by an ice plug in about the same location. Deerfield River is the gainer of seven or eight miles of stream, and 20 to 25 square miles of land.

A lesser diversion has been suggested in the northeast corner of Whitingham township. At Two-way Pond two miles northwest of Jacksonville the drift is thick, the old rock valley is advanced mature and there seems no reason in the rock forms for a divide here. The pond at Jacksonville and the stream through it, seem to be out of topographic adjustment, for the lake lies in a narrow rock valley scoured severely on both sides, while just upstream above the lake the valley widens out much more maturely. The rock is of the same formation essentially along the strike and would seem to present no reason for such discordance. Rock is not known northeast of Two-way Pond for a mile or more. The drift is thick covering all. A tributary from the north coming into Whitingham township almost exactly in the middle of its north line, at present turns west and flows down into the big reservoir, making a distinctly barbed turn.

With all these facts in mind it is suggested that this barbed tributary formerly flowed southeast toward and beyond Two-way Pond, and that the narrow valley it now occupies from the turn down to the reservoir, is a combination of a transgressed col and a short stub valley. It is further suggested that the drainage from one to three miles north of Jacksonville and a little farther east than the Whitingham town line, flowed westward and southwestward into the mature valley just southeast of Two-way Pond and then on southeast as East Branch North River. This branch seems to show rejuvenation from the Connecticut River up as far as Jacksonville. In this plan for the old drainage probably no tributary came down through what is now the Jacksonville Pond. That notch was no doubt cut through in glacial time partly by diverted drainage and partly by the ice scour.

Another case of drainage modification is around Sadawga Pond, but thus far we have no suggestion to make as to what has happened. We are sure that the drainage of the region did not go out southwest toward Sherman, although the hill topography strongly suggests that outlet. Rock is known all across the col between the 1,600 and 1,700 foot lines and almost all the way above the 1,700 foot line, while the pond itself is not up to 1,680 and, of course, the valley floor, some distance lower.

There have doubtless been other small drainage modifications, but we note nothing as large as these. The main stream is certainly essentially in its preglacial valley, entirely across the area.

Ice Erosion.—Rock scorings or striae are found occasionally on surfaces strong enough to retain them, but usually they are very indistinct or obliterated by weathering so that little can be learned from them. Their testimony wherever found in the uplands agrees with the general evidence from New England, that the ice came from the north and moved south, and was modified in its directions locally by local elements of topography. Valleys led it here and there, hills and ridges tended to push it aside from the north-south direction. The highest hills were scored as thoroughly as any, indicating that the ice was thick enough over them to be even there a powerful agent of erosion.

It is impossible to separate the erosive work of the early ice invasions from that of the Wisconsin and almost as difficult to ascribe any drift forms to the older ice sheet, but no doubt the earlier sheets played no small part in touching up the topography and putting it in its modern form.

Several steep slopes were mentioned under Relief. Some of these are due to ice work. Perhaps the finest example of ice steepening and trimming is found in the Deerfield valley wall west and south of Readsboro. The whole valley wall here has been smoothed and very considerably steepened by the ice. No doubt preglacial river work gave it a general concave form, but the ice has trimmed, smoothed and rounded it until it looks like the wall of an amphitheater extending from the town down the valley nearly two miles. The work was done by the ice as it turned here under the directive influence of the preglacial valley form—ice from the north and northwest turned here to the southeast.

In a similar way the east and northeast sides of the hills about four miles up river from Readsboro were trimmed. The lower slope a mile above the old Davis Bridge and the big dam, on the west side of the river has been made smooth and regular by ice erosion, and above it on the county line and west of the same, on the northeast side of the hill is similar steepening. The ice certainly had trouble in the vicinity of Davis Bridge on all sides, for it has steepened all slopes some. East of the river the same smoothening and over-steepening is apparent. Even the north end of the large hill against which ice must have pushed as it came down the valley between these two steepened slopes, is by far the steepest slope of the hill.

South of Readsboro Falls both sides of the valley are over-steepened, the left bluff near the falls and the right, a mile down stream. The ice no doubt gave finishing touches to these slopes, which were already steep because of the stream transgression at this place. Again the ice pushed against the spur standing out into the valley from the west a half mile or so above Readsboro. This spur was so steepened that it could not stand and great boulders have broken loose and tumbled down the slope in gross confusion. Similarly the east bluff opposite has been steepened until in postglacial time, many boulders have split off and tumbled down toward the valley. These slopes are both very difficult to climb because of the loose huge boulders and fallen logs over them.

No doubt the steepened slope southeast of Heartwellville on the right bluff is ice trimmed also. Similar trimming shows just below Jacksonville on the west side of the first hill on the left of the valley, and opposite this to a much less extent; also about one mile farther down stream on the right and still farther down on the left. Such trimming shows the power of the ice even when a continental sheet only is present. The under part moulds itself to the valleys and hills, and trims and shapes them as it goes.

It is probable that some high level slopes have been modified also. One and one-half miles south of Howe Pond and near the western side of our area the east side of a hill has been steepened, and probably the eastern side of Jilson Hill has been similarly influenced.

Nearly all, if not all, of this work is due to scour. Plucking is scarcely known in the area. Possibly a little may have occurred near the big power plant and up-stream for a mile on the same side. Ice certainly went from north to south over this row of hills in the loop of the river, without being seriously deflected as it was in several other places. The jumble of boulders below the crests on the south side of the hills seems to indicate plucking. One or two hills just east of the area mapped, show the characteristic steep lee side as if they had been plucked also. Figure 18.

General ice erosion, including the removal of about all of the residual soil and weathered rock, was done everywhere as is shown by bare rock in scattered patches in hundreds of places and by the sharp contact between bed rock and mantle wherever the contact is exposed. Nearly all hill tops either over the top or on the least protected brow show bare rock ledges. Many acres are so thinly covered as to have but little agricultural value. Probably the largest exposures of ledges in the area are about two miles west from Readsboro. These can be seen clearly under favorable lighting for more than three miles. In several places the erosion has resulted in the leaving of furrows with rock ridges between. The furrows may be 20 to 100 feet wide and 10 to 40 feet deep and the ridges of similar size. These were first noted on the east-west road southwest of Sadawga Pond over the back of the long rounded ridge that borders the pond area on the southwest side. Here the rock ribs are 20 to 50 feet wide and nearly flat on top, also nearly bare. The troughs between them are of similar width and as much as 20 to 25 feet lower than adjacent ridges. Probably six or seven of each occur here where the road crosses them. The troughs are marshy or actually contain lakes. Essentially the same forms occur on the hill east of Readsboro in the loop of the river. The ridges and troughs are mostly larger, but are not well shown on the topographic map. They run nearly north and south. The lower troughs are well floored with drift, but the higher ones nearly as far east as the county line contain but little soil. Enough is present so that trees have grown over all. Some of the troughs are so shut in by drift as to be marshy. These troughs or furrows are undoubtedly ice carved. Every inch of their sides, and of the floor where visible, and of the ridge tops between is

PLATE XXIV.

A part of the camp, 1924. Looking east. The private road goes up the slope between the old rock wall on the left and the thick drift masses on the right. The river is 600 feet to the right or south of the road here and has not disturbed this drift at all.

smoothed and marked as by glaciers. They are in the direction of ice movement. They are similar to, but sometimes larger than, the deep furrows on Kelleys Island in western Lake Erie, which have been properly ascribed to glacial erosion.

While there has been this extensive stripping of the rock mantle everywhere, there is a remarkably small amount of really foreign material in the drift. If foreign stuff is largely present it is in the form now of sand and clay or is identical in character with our country rock. Nearly all boulders are just such rocks as occur in place in the area and near to the north. The most conspicuous foreign material is quartzite, of which there are a good many boulders. No quartzite that could have furnished these samples is known in the area nor for 15 miles to the north. It is frequently possible to map a dike of peculiar rock fairly closely on the basis of frequency of boulders. The largest dike in the area, a dark green dioritic rock, was found by tracing its boulders, and patches of marble were located once or twice by fragments in the drift. They never persist far from the outcrops.

Ice Deposition.—More significant in present topography than the erosion forms are the drift forms. A mantle covers nearly all. The drift varies in thickness from mere traces to many scores of feet. It is, in the main, thin on the uplands and thick in the valleys, thus its aggregate effect has been to subdue the relief. This is true also with reference to the placing of the drift over the slopes. In many places it has been smoothed into depressions, concavities on slopes, or against steeper slopes, and in each case so located as to round out the topography and reduce the surface relief.

In the larger preglacial valleys the drift is often very deep. In places the Deerfield was filled with it more than 250 feet. Rarely has the stream to date cut through all the drift unless it be near the valley wall so as to come down upon the wall and not in the axis of the valley. In the curve a mile above Readsboro great quantities have been smoothed into the valley so as to leave a sag between the drift and the right valley wall. Plate XXIV. Presumably a lower sag crossed the drift on the left side somewhere, for the stream now goes round the curve on that side never having modified drift forms on the opposite side. Plate XXV. The stream has encountered ledges on the outside of this curve for a few hundred feet, but nowhere else in the whole curve. The top of the drift is 200 feet higher than these ledges and may well be thicker than 200 feet in places.

Again the river is on ledges on the left side just as it goes into Readsboro, this time on the inside of the curve, and the drift is apparently fully 200 feet thick on the right side.

Drift seems to be very thick in the valleys converging on Heartwellville, but no stream has cut through it near there, so one can but guess at the thickness. Great fans have been built out into this open area by some of the streams coming into it. Much of the way West Branch flows on bed rock, but just below the half way point between the falls and Readsboro the drift is very thick and the stream has been forced to take a course close to the right side and carve a rock gorge, while a mountain of drift occupies the major part of the valley on the left side. This feature is not well shown on the topographic map.

In the central part of Whitingham township are two rock valleys draining north at present. The village is at their junction. Sadawga Pond occupies the east valley, and an arm of the big Whitingham reservoir occupies part of the other. The surface of water in Sadawga Pond is about 1,675 feet above sea-level, while that in the other valley is about 1,500 feet and yet the water is probably deeper in the latter. Apparently the western valley has not been carved much in postglacial time, for an esker nearly a mile long, lies in the valley undisturbed save by man's shovel. Certainly little erosion has occurred in the eastern valley. Probably both valleys are much as the glaciers left them except that man has enlarged Sadawga Pond and set back water from the big reservoir into the west valley. There is very little drift in the latter, while it is obviously very deep in the other. This accounts in part for the broad nearly level area under and around Sadawga Pond.

Howe Pond in the western part of the area also lies in a valley much filled with drift. The lake has been larger than at present and the stream was lowering it by cutting out the drift in the outlet, but man has now built a small stone dam and checked the process.

In the valley southwest of Lord Peak one and one-half miles southwest of Readsboro the drift is very thick, but it was not so placed as to hold water in and make a lake. Northwest of Whitingham less than two miles is a tamarack swamp not so mapped on the Wilmington sheet, but covering scores of acres. It is in a valley deeply drift-filled and partly obstructed, but left open enough to the south so it does not contain a lake. A similar distance north of Jacksonville is a filled area which is partly marshy and contains two small lakes. It is more than likely, as suggested elsewhere, that a broad valley leading southwestward was filled nearly full here.

Drift is very thin over the slopes west of Readsboro Falls from Heartwellville valley to Howe Pond. While outcrops are not at all continuous they are generally frequent over nearly this whole area. The large hill between Sadawga Pond and the river is also rather thinly covered. The slopes east of the pond and for a couple of miles southeast are also rarely more than just covered.

Special Drift Forms.—The Oberlin party worked in 1920 in the vicinity of Wilmington, Vermont, and was much interested in the special drift forms systematically deployed in that area, so it

PLATE XXV.

A few hundred feet up the private road from Plate XXIV and looking in the opposite direction. The meadow in the left and center is the mass of drift in the valley. The road is the same as in Plate XXIV following up the sag between the drift and the rock wall. The river is in the sag swinging round from the left to the center of the picture. Readsboro in the middle distance and Lord Peak, a monadnock above the second peneplain, on the sky line.

was with some disappointment that their almost complete absence was discovered in the Readsboro area. While there are moraines, eskers, and moraine terraces almost universally present in the valleys leading away from the Haystack range, testifying eloquently to the occupation of the slopes and valleys by valley glaciers after the main ice sheet was gone, in this area five to ten miles farther south there is nothing of the sort. Eskers are the only details of form left as the ice melted away.

Southwest from Whitingham about two miles, or just south of where the road from Readsboro turns north and an old dirt road leads south, there is found a well formed esker ridge. It may be seen in the road and on both sides in squares g-30 and f-31 also i-j-30. It has been opened in several places for sand and gravel, which is very abundant. The esker is a typical serpentine ridge, in some places divided, varying in height from a foot or two to about 30 feet. The road follows it southwestward. Another esker occurs in the valley west of Whitingham. This runs lengthwise of the valley for a half mile or more. It can be seen from the new road that crosses this valley between Whitingham and the big dam. The ridge of gravel occurs on the east side of the valley quite a distance south of this road in the edge of the woods, and with a winding course leads northward until it goes below the water on the west side of the valley, some distance north of the road. It has been extensively opened for gravel.

Eskers are the beds of subglacial streams built by aggrading waters in a tunnel under a waning glacier. Presumably there is very little or no flow of ice, else a serpentine ridge would be disturbed and mussed. Thus an esker in good form is no evidence of local glaciers for they are made after the ice sheet ceases to flow actively, and during the final melting of the ice.

In the main valley are found some gravel and sand deposits laid by waters from the melting ice. Small deposits in two or three places around Readsboro still show. Larger masses occur up stream a mile or two now carved into terraces. These are around the adit and especially opposite. Other gravel deposits were made and preserved in the turn of the valley two miles above the Davis Bridge. These were subsequently carved into terraces and were mapped in 1920, but the water of the big reservoir covers them completely. It is probable that outwash gravels were laid all the way down the valley from the moraines near Wilmington to Massachusetts and farther, and that the patches we now find are remnants of them, left after the streams have been operating upon the deposits through all postglacial time.

Postglacial Stream Work.—As the ice withdrew foot by foot, the streams took possession. Thus they have operated longer in the southern than in the northern part. The area is so narrow, however, that the difference in time is short, and is not perceptible in erosion forms. In fact all postglacial time measured in terms of what has been done by streams is short.

To appreciate its brevity note that outwash has not been removed entirely in the valleys, hence valleys are not even as deep and wide as they were before the ice came. Eskers still remain in some valleys. Drift forms occur just as the ice left them in several places in valleys, showing that the streams have not yet had time to clear out the material the glaciers put into their old valleys. Falls and rapids and steep grades, in all stream beds still persist. Lakes are undrained, even unfilled as yet. Marshy tracts still interfere with agriculture, but when drained they may contribute acres of rich black soil. Water power is still a great asset and will be for ages to come.

But with so much not done it is worth while to observe what has been done. Where opportunity offered some streams have carved deeply into drift. Witness the deep cuts near Readsboro and a mile up-stream and others on the West Branch. The falls up this West Branch have only receded a short distance. They seem to have begun as rapids and hence had little or no gorge at the start. They are no doubt related to the stream diversion here, discussed elsewhere. Potholes have been made in great numbers in the bed rock for a couple of miles below Readsboro Falls. Some are large enough for a bath tub, others are but inches across. Potholes are notable features in most streams that are on bed rock, but the schist in this particular area lends itself to pothole carving more readily than most of other rocks.

In general the streams occupy preglacial valleys and have done relatively little toward adjusting to them. Rapids and more level reaches alternate on all streams but the main one. In that the grade is fairly uniform, but in the scores of little laterals the grade is very variable and vastly greater than in the Deerfield. Valley floor slopes of 300 to 500 feet per mile are common in the laterals, while 20 to 40 feet per mile is about the range in the large river.

Streams are not in the centers of valleys in many cases. Howe Pond is fairly symmetrically placed with reference to the contours near it, but with reference to higher contours it is close to the north side of its valley. Drift is thick on the southern slopes, filling in and crowding the lake over. In like manner its outlet is not centrally placed. It is easily four or five times as far from the 2,000 foot contour on the south side as from the same on the north. The same asymmetry with reference to higher lines is obvious. Even the Deerfield is far to one side of its valley in some places. In the northern half of the area where it flows in general southward the eastern slopes or valley walls are generally much gentler and all but the lowest lines are much farther from the stream on the east side. In the vicinity of the big dam the symmetry is notable, but below the adit the lack of symmetry is just as striking. Drift deposition certainly has something to do with this, and the large curve in the river through Readsboro has been an important factor.

Nearly all the smaller streams have in their upper courses practically no valleys yet. Postglacial time has been so short that only channels have yet been made and some of these are quite inadequate. So far then as preglacial valleys are concerned, drainage is good, but where drift has interfered, postglacial work is so immature that drainage is really very poor.

The events of the glacial period kept the streams from the main job while the glaciers were here and left a little drift in the way of immediate resumption of the normal work, but after all one must look upon the whole problem of the glacial period as an extremely ephemeral item as compared with the work of base leveling the region after a 1,400 foot uplift. It caused but a momentary interruption for the streams, an interruption which is now nearly over, for the streams are already touching the rocks in places and the ice is long ago all gone.

Each stream began its postglacial task by removing drift from the preglacial valleys, preparatory to a new attack on the rocks. So short has postglacial time been that most of the streams are still at this preliminary work. Great tasks are ahead if the valleys are all to be made mature or old, and the region reduced to a peneplain near the new sea-level. The removal of the drift from the valleys is but the merest trifle compared with the greater task.

With the land so high as it now is above sea-level—its base-level—active erosion is unavoidable whenever and wherever water can run. A continuation of the drift removal, associated with and followed by rock excavation to the maximum depths will follow now. Then will come the widening of valleys, development of flood plains, tributary valleys and finally the attack of divide areas until the ultimate stage of erosion shall have been reached—the peneplain with a few monadnocks. With this vision of the task ahead it is obvious that postglacial erosion to date is very meagre.

Weathering, erosion, transportation are the chief geologic processes in operation here now. Sedimentation ceased long ago. Diastrophism is not now apparently in operation. Vulcanism, metamorphism and folding are not in play. There is no guarantee that any or all of the processes may not some day again become active. We simply can say that at present they are inactive and streams are free to carry on their work uninterrupted.

ECONOMIC RESOURCES.

Prospects for Metallic Minerals.—In spite of a good deal of of interest, not to say mild excitement over possible wealth in metallic ores in the Readsboro region, it seems necessary to state that the place has no promise of importance in this direction.

Gold and silver so ardently sought at times by man are not to be found here in workable quantities. Traces of the former have been found, fake assays have made disturbing returns, but the stern fact remains that more money has already been put into the gold and silver mining business of this little region than has ever been taken out or is liable to be taken out, no matter how much may yet be invested.

Copper and nickel have also been reported, but are only available as curiosities in the scantiest traces. Iron, the metal above all metals, in man's requirements today, only occurs in one ore mineral, magnetite, and that only in scattered tiny crystals absolutely unworkable. The sulphides of iron, pyrite and rarely pyrrhotite are also widely scattered, but they are never considered an ore of iron even when concentrated, and this region cannot possibly enter the market. A few masses of pyrite have been found in the drift, notably one or two up Readsboro Falls road about a mile above Readsboro, but these occurrences should never excite the finder. They have no commercial value.

Aluminum has been said to occur here. The statement properly qualified is true. Aluminum is a constituent of all micas and feldspars which are common nearly all over the area. It is also a part of all clays and the glacial drift. Chemists can get this aluminum out and make sheet or bar aluminum of it, but it is not a large ingredient of these substances and cannot be extracted and put on the market to compete with that taken from the aluminum ore, bauxite. Bauxite does not occur in the region.

There is no metal that can be extracted with profit, to be found in our area. The chief values with geologic connections are soils, water, and water power, building and road materials, gravels and sands.

Soils.—Soils are largely glacial drift and are of good quality and long life. Some are so free from limestone that they become a little acid. Two conditions should be considered in selecting a soil. 1, Its physical condition, thickness, stoniness and tilth; 2, its water—drainage and washing or eroding are the vital items. Does it drain well so it can be cultivated early in the spring, and promptly after rain? Does it lie so as to wash badly by running water? There are small areas where the soil is too thin or too stony, but most of the area is covered with mantle enough to serve agricultural purposes. Larger areas are too wet, some even boggy, and many patches are springy above so that they receive seepage and are constantly too wet to cultivate. A few slopes are too steep and rocky and should be left in forest. But these soils unusable are really only a small area. Much land can actually be plowed, larger areas should be in grass to mow, and probably still more should be in grass for pasture, while forests, sugar bushes, and game preserves should take the rest.

Water Supply and Power.—The rainfall is ample and usually well distributed, but if three or four weeks of the growing season do go by with scanty rains the hay and crops suffer more than they do in regions with a heavier clay soil. Springs are frequent and serve most of the country homes abundantly. Streams are frequent and where too large a village has grown up to be supplied with spring water. Some small streams can be ponded back to serve the community. The ponding of waters for power purposes is a common practice. Formerly most of the small streams were made to serve, but now most of the small powers have been abandoned and large plants are built on the main streams as frequently as the fall permits. The whole problem of the river is surveyed. All fall is considered, all possible storage basins are measured and all sites for dams scrutinized, then selection is made of the best site to use the most power. Nearly every generation has improved on the work of its predecessors in the conservation of power. At present one large plant in the Deerfield valley about three miles up-stream from Readsboro monopolizes essentially all the power on the main stream in our area, and up-stream four or five miles farther. This project takes the water from the stream three miles above Readsboro at the big dam, which is 180 feet high, and conducts it two and one-fourth miles through a tunnel and returns it over wheels at the foot of great penstocks, to the stream two miles below Readsboro, concentrating in one fall and power plant nearly all the fall of the stream for twelve miles. Sadawga Pond, enlarged, serves as a subsidiary reservoir for the same power plant. Howe Pond is used as a water supply for the village of Readsboro.

Building and Road Materials.—The materials for building and roads are abundant. Some of the marble could be used for building, but most of it is too badly fractured, and too rich in micas and other accessories due to its mixed sedimentation and its metamorphism to make suitable building stone. In several places the schists are cleavable and could be quarried. One such place is near the railroad station at Readsboro, and also below the local dam in the gorge. Here the stone is a gray quartz-mica schist and could be gotten out in considerable quantities. Other occurrences are farther from town and the railroad, but there are several places that could be opened up. Road materials have included, until recently very little but the gravels and sands, but there are quantities of mica schists which can be crushed and spread on the roads and dressed with a little crushed marble as a binder, making a very fine road. This schist is beginning to come into use and no doubt will become more and more significant. It can be gotten out with steam shovels in places beside the road, preceded if necessary by blasting, crushed and put right on the road with no serious difficulties of any sort.

The topography is mature enough to make road building and maintenance a fairly simple matter. Lines can be laid out with so low a grade that travel is easy and washing nearly impossible. Of course some roads up to scattered farm houses present larger difficulties, but ways are being found now to get out and in over an easy grade from almost every occupied house.

Gravels and sands are generally along the present or ancient streams. One of the finest sand banks of the area is opened in an esker a half mile south of the main road from Whitingham to Readsboro, leaving the main road at the turn marked "Readsboro three miles." Referring to the system of squares this esker is in f-g-30-31-32 along the diagonal, woods road. Another esker occurred in the valley running north and south, west of Sadawga Pond. It has been extensively worked and part of it is now under water. East of the first esker mentioned are several short sections of esker, probably parts of the same subglacial drainage system, which could be used for sand or gravel, but so far have not been opened.

Sand and gravel can often be gotten in places along some of the present streams in outwash deposits made by glacial waters during the waning of the ice sheet. There is, however, no adequate supply of either sand or gravel and most of it is not well enough sorted to be very valuable.

The marble mentioned as a poor building material has a larger use as a corrective for acid soils. It is quarried and crushed and put on the land and allowed to do its work—neutralizing the acid. Good effects have been shown to follow its use for 20 years. It has been burned both for lime for plaster, and for soil dressing. The former use is probably a thing of the past, but as a soil dressing it is much more active and quicker in its effects than the crushed rock. Much more use of the marble could and probably should be made as a medicine for soils.

The marble at Sherman has been shown by actual use to be valuable for the manufacture of calcium carbide. During the early part of the war a plant for its manufacture was constructed at Sherman at a large cost. A very excellent product was made for six or eight years, but about a year ago the plant shut down and now it is being dismantled. There seems to be no local reason why the process should not be successfully carried forward. But the place is some distance from a coal supply and out on a stub railroad expensive to operate and these things are handicaps. On the other hand the plant is far enough from industrial centers to have little or no detrimental contacts with the large labor problem. Further, the product is claimed to be very superior. The marble is abundant and very easily gotten from quarry to plant. The geologic and geographic conditions may be considered very satisfactory.

When all is said that can be said for the geologic resources of this region, it has to be admitted that there is no foundation for any considerable industrial development. Water power is abundant and is transmitted far, and not much used on the ground. By all odds the most promising industry is agriculture in its several phases, dairy and beef cattle, sheep, hogs, poultry, hay, potatoes, apples, maple syrup and other subsidiary branches. The Vermonter has long lived happily and successfully in this region and there is yet a fine opportunity for just as valuable a human occupation of the valleys and slopes.

MINERAL RESOURCES.

G. H. PERKINS.

The age-old saying, "Line upon line, precept upon precept," seems still needed in Vermont so far as concerns metals and coal.

Over and over again in several former Reports the Geologist has tried to emphasize the facts respecting Vermont minerals, but many samples of supposed ore (they are more frequently thought to indicate gold than other metal) come to this office during the year.

People should remember that for more than a hundred years the small area of the State has been diligently searched for metal deposits of such size as to warrant the expense of developing, without favorable result, although in some cases a not inconsiderable amount of money has been put into holes from which nothing, or very little, of value, could be taken out.

It is also to be remembered that in the whole history of mining in Vermont not a single mine, though many have been worked, has ever been a paying proposition for any length of time. A very few have, for a longer or shorter time, paid more than expenses, but none for long and by far the greater number have given no return but have proved a total loss.

Metals of various sorts are to be found in Vermont, but always in so small quantities that the vein, mine, or whatever, was of no value. We have every scientific reason to predict that no such deposit of metal, as would warrant the expense of development, will ever be found in this State and that, this being true, there is no use in trying to find it.

As to coal, the geological conditions in Vermont are such that coal cannot be found here. The reason being that coal is formed from deposits of vegetable matter and when the rocks of Vermont were deposited, vegetation such as was necessary to supply material which, under proper conditions, would form coal could not exist, and did not for ages after.

I do not forget that these facts have been published in former Reports, but, as already indicated, it seems necessary to repeat them.

Always the mineral wealth of Vermont must be limited to quarries. The only mines in Vermont, the only sort there can be, are those producing talc.

Asbestos, found in several localities, has been very thoroughly exploited in this State, but has so far nowhere proved profitable and all the asbestos mines are now closed. Talc will be considered later.

As for several years past, Vermont leads this and, I believe, all countries in the value and production of granite and marble, and in the United States is second, though not a very close second, in slate to Pennsylvania.

GRANITE.

As everyone acquainted with the granite business in Vermont knows, it is mainly confined to a few localities, all east of the Green Mountains, and at each of these localities there are a greater or lesser number of companies. The Barre district, Woodbury, Hardwick, and Montpelier, are the more important localities, while at Waterbury, Northfield, South Ryegate, Groton, Barton, Concord, Bethel, Newport and several other towns there are, or have been recently, granite quarries and cutting sheds in operation. In these places there are, as will be seen from the lists below, a large number of companies—much larger than of all other stone-working companies combined.

By comparing lists of these companies one will notice that from year to year there is considerable change in the personnel or, at least, in the firm name; old companies disappearing, new ones formed. On this account frequent revision of the lists is needed.

The lists given below, while possibly not without error, are nearly so. In preparing them I have been greatly aided by Mr. B. E. Mitchell, Secretary of the Granite Manufacturers Association of Barre, also by the Woodbury Granite Company for Hardwick and Woodbury and others.

Of the Barre companies the larger number are non-union, though between thirty and forty are in the Union. How this is elsewhere I am not able to say.

At times during the last two years, because mainly of labor troubles, the granite business has been somewhat irregular, but it is reported as on the whole pretty good.

I am not able to give the average value of all sales of granite, rough and dressed, for the last five years, but, approximately, they have been from $3,500,000 in poor years, to $6,500,000 in the best years. This gives for an average $5,500,000, which I think is less than is the true amount for the whole State.

LIST OF GRANITE COMPANIES IN VERMONT, 1924.

BARRE DISTRICT.

NON-UNION COMPANIES.

Aja Granite Co., U., Montpelier.
Anderson-Friberg Co., Inc., Barre.
Anderson & Johnson, Barre.
Arioli & Co., G., Montpelier.
Barclay Bros., Barre.
Barre Granite Mtl. Wks., Montpelier, Q.
Barre Memorial Co., The, Barre.
Batchelder & Co., Inc., E. J., Barre.
Beck & Beck, Barre.
Bellucci Granite Co., A., Montpelier.
Bilodeau & Co., Inc., J. O., Barre.
Bond Gr. Co., Inc., George E., Barre.
Boutwell, Milne & Varnum Co., Barre, Q.
Brown & DeMerell, Barre.
Brusa Bros., Barre.
Burke Bros., Barre.
Buzzi Granite Co., Barre.
Canizo & Co., E., Barre.
Canton Bros., Inc., Barre.
Capitol Granite Co., Inc., Montpelier, Q.
Carroll Bros., Barre.
Carswell-Wetmore Co., Inc., Barre.
Caslani Bros., Barre.
Celente & Bianchi, Barre.
Chioldi Bros. Granite Co., Barre.
Cole & Son, William, Barre.
Columbian-Artistic Gr. Co., Montpelier.
Cook & Watkins Mfg. Co., Inc., Barre.
Comolli & Co., Barre.
Cross Bros. Co., Inc., Northfield.
Davis Bros., Inc., Riverton.
Debitetto & Caccavo, Barre.
Dessureau & Co., Barre.
Doucette Bros., Montpelier.
Desilets Granite Co., Inc., Montpelier.
Eastern Granite Co., Montpelier.
Eureka Granite Co., Inc., Montpelier.
Excelsior Granite Co., Montpelier.
Freeman & Wasgatt, Barre.
Gelpi Granite Co., Barre.
Genest & Beaulieu, Inc., Barre.
Gill & Co., C. P., Montpelier.
Giudici Bros. & Co., Barre.
Glysson & Co., Inc., E. C., Barre.
Grearson & Lane Co., Inc., Barre.
Green Mountain Granite Co., Montpelier.
Harrison Granite Co., Barre.
Hebert & Ladrie, Barre.
Hedwall & Co., Inc., Paul, Barre.
Higuera Granite Co., M., Montpelier.
Hinman Co., Inc., H. P., Barre.
Industrial Granite Co., Barre.
Johnson Granite Co., The, Montpelier.
Johnson & Gustafson, Barre.
Jones Bros. Co., Inc., Barre, Q.
Jurras Granite Co., Inc., Montpelier.
Kent & Russell, Inc., Barre.
LaClair & McNulty, Inc., Barre.
LeClerc, R. A., Montpelier.
Lillie Granite Co., Inc., Montpelier.
Littlejohn, Odgers & Milne, Barre, Q.
Lucie Granite Co., Montpelier.
Marr & Gordon, Inc., Barre.
Marrion & O'Leary, Inc., Barre.
Menard & Erno, Montpelier.
Mills & Co., Montpelier.
Milne Granite Co., The Wm., Barre.
Mutch & Loranger, Barre.
McDonnell & Sons, Inc., Barre, Q.
McGovern Granite Co., Inc., Barre.
National Granite Co., Inc., Montpelier.
Nelson & Mattson, Barre.
Newcombe, Thomas J., Barre.
Novelli & Calcagni, Inc., Barre.
O'Clair Granite Works, C. L., Waterbury.
Olliver Granite Co., Barre.
Olson & Nelson, Barre.
Pando Granite Co., Northfield.
Parnigoni Bros., Barre.
Parry & Jones Co., Inc., Barre.
Peerless Granite Co., Barre.
Pelaggi & Co., Inc., Northfield.
Perry Granite Corporation, Waterbury.
Phillips & Slack, Inc., Northfield.
Pirie Estate, Barre, Q.
Pratt Granite Co., Inc., Barre.
Provost Granite Co., Inc., Riverton.
Puente Granite Co., Barre.
Redmond & Hartigan, Barre.
Rissi & Son, Barre.
Robertson, J. C., Barre.
Robbins Bros., Barre.
Ross & Ralph, Barre.

Roux Granite Co., Barre.
Russell & Brand, Barre.
St. Onge & Son Granite Co., Montpelier.
Saldi, Rossi & Co., Barre.
Sanguinetti, A., Barre.
Saporti & Co., Wm., Barre.
Sector & Co., James, Barre.
Sheridan & Poole, Barre.
Sherra Granite Co., R., Barre.
Smith, E. L. & Co., Barre, Q.
South Barre Granite Co., Inc., Barre.
Standard Granite Co., Barre, Q.
Straiton, George, Barre.
Star Granite Co., Montpelier.
Tosi & Co., E., Barre.
Union Granite Co., Barre.
Union Granite Co., Inc., Waterbury.
Usla & Revilla, Barre.
Valz Granite Co., Barre.
Vermont Manufacturing & Quarry Co., Barre, Q.
Victory Granite Co., Barre.
Wells & Lamson Quarry Co., Barre, Q.
Wetmore & Morse Granite Co., Barre, Q.
World Granite Co., East Barre.
Young Bros., Inc., Barre.
Zorsi & Co., G., Barre.

UNION COMPANIES.

Alonzo & Aja, Barre.
Abbiatti & Fontana, Barre.
Bianchi & Sons, Chas., Barre.
Canales & Gomez, Barre.
Central Granite Co., Barre.
Crescent Granite Co., Barre.
Carley & Cummings, Barre.
Cedrone Granite Co., Barre.
Cenci & Bardossi, Barre.
Eagle Granite Co., The, Barre.
Gerard & Barclay, Barre.
Gomez Bros., Barre.
Hoyt & Milne, Barre.
Imperial Granite Co., Barre.
Liberty Granite Co., Barre.
Lawless Granite Co., Barre.
Martinson Estate Co., Barre.
Modern Granite Co., Inc., The, Barre.
McColl & Abare, Barre.
North Barre Granite Co., Barre.
New Starr Co., The, Barre.
Orlandi, A., Barre.
Parnogoni, B. & Co., Barre.
Rosa Co., F., Barre.
Ravilla Granite Co., J., Barre.
Shield & Co., Waldron, Barre.
Steele Granite Co., Barre.
Twentieth Century Gr. Co., Barre.
United Granite Co., The, Barre.
Vanetti Granite Co., Barre.
Valdivielso & Esteran, Barre.
Webster Granite Co., Barre.
Bettini & Ratazzi, Barre.
Barre Granite Co., Barre.
Bardossi Granite Co., Barre.
Corskie Co., J. P., Barre.
DeRegibus Granite Co., Barre.
Dunghi & Groppelli, Barre.
Fontana, E., Barre.
George Granite Co., Barre.
Gomez, Lang, Pena Bros., Barre.
Hastings Granite Co., J., Barre.
Lawson, Alex., Barre.
Lion Granite Co., Barre.
Lorenzini, C., Barre
Milne, Alex & Co., Barre.
Movalli & Co., J., Barre.
Nicora Granite Co., A., Barre.
Native Granite Co., Barre.
Palaoro Bros., Barre.
Rex Granite Co., Barre.
Rossi, Granite Co., Barre.
Rabaloli & Rossi, Barre.
Sartell & Grierson, Barre.
Simonelli & Fontana, Barre.
Usle & Parajo, Barre.
Verd Mountain Gr. Co., Barre.
Venetian Granite Co., Barre.
Williamstown Granite Co., Barre.
Zampieri & Buttura, Barre.

America Granite Co., Montpelier.
Everlasting Gr. Co., The, Montpelier.
Liberty Granite Co., Montpelier.
Pellon Granite Co., I., Montpelier.
Bonazzi & Bonazzi, Montpelier.
Doyle Gr. Co., M. J., Montpelier.
Ortiz Granite Co., Montpelier.

Politti Granite Co., Northfield.

Montpelier—See Barre District.
Northfield—See Barre District.
Waterbury—See Barre District.

HARDWICK AND WOODBURY.

Ambrozini & Co., M., Hardwick, Quarry at Woodbury.
American Granite Co., Hardwick, Q.
Bailey, Geo., Hardwick, Q.
Calderwood, Fred., Hardwick.
Carter Granite Quarries, Inc., Mackville.

Couhig, M. J., Hardwick.
Crystal Brook Granite Co., Hardwick.
Eureka Granite Co., Hardwick.
Fletcher, E. R., Woodbury, Q.
Good, P., Hardwick.
George & Somes, Hardwick.
Govaraldi & Co., G. V., Hardwick.
Hay, John, Hardwick.
Hardwick Polishing Co., Hardwick.
James Granite Co., Hardwick.
Kennedy, J. A., Hardwick.
Nunn & Fordyce, Hardwick.
Murch, E. R., Hardwick.
Purdy, F. A., Hardwick.
Robie, L. S., Woodbury, Q.
Ralph & Co., Geo. Y., Hardwick.
Taylor, Alex., Hardwick.
Thomas, A. B., Woodbury, Q.
Woodbury Granite Co., Hardwick, Woodbury, Q.

GROTON.

Groton Quarry Co., Q.
Hendry & Mille.
Hendry, C. H.
Hosmer Bros.

SOUTH RYEGATE.

Blue Mountain Granite Co., Q.
Newbarre Granite Co., Q.
Ryegate Granite Works Co., Q.

BARTON.

Barton Granite Co., Q.
Crystal Lake Granite Co., Q.
Lewis, L. R.
Roy Monumental Works.
Roy, T. F.

CONCORD.

Lillecrop & Son.
Moose River Granite Co.
Smith Granite Co., L. E.

ADAMANT.

Hughes Granite & Quarry Co., Q.
Orzella, Frank & Mazzi, Frank.
Steele Granite Co.
Shields, Waldron.

OTHER LOCALITIES.

Haselton, C. S., Beebe Plain.
Stansted Granite Quarry, Beebe Plain.
Presby Granite Co., Leland, Dummerston, Q.
Newport Granite Co., Derby, Q.
A. J. Goss, West, Danville, Q.

In the above lists those marked Q. have quarries. The others manufacture the rough stock from quarries.

MARBLE.

Although marble is more widely distributed over the State than other building stone it is found mainly only west of the Green Mountains.

Nearly all worked quarries are located in Rutland County and are worked by a few companies, as follows:

Clarendon Marble Company, Clarendon.
Eastman Marble Company, Rutland.
Vermont Marble Company, Proctor, main office.

All the above have quarries and manufacturing plants.

Probably there is nowhere a marble company as large as the Vermont Marble Company which has mills and offices in—beside the headquarters in Proctor—Rutland, West Rutland, Florence, Middlebury and elsewhere. Quarries at Proctor, West Rutland, Florence, Brandon, Danby, Dorset, Swanton, Isle La Motte, Rochester, etc.

A full account of the marble industry in Vermont from its early days may be found by anyone, especially interested, in the Ninth Report of this series, which can be obtained at the State Library.

The total value of the marble sold in Vermont varies from year to year, but is not less than $4,000,000 to $5,000,000.

SLATE.

The third great stone industry in Vermont is the production of slate.

The productive slate region of the state is, like the marble area, mostly in Rutland County, west of the marble and it extends into the State of New York. In some cases the quarries are at least partly in one state and the business offices in the other.

East of the Green Mountains, especially in Northfield, there are quite extensive beds of slate, but they have not been continuously worked.

The following is a list of slate companies at present producing:

LIST OF SLATE COMPANIES.

CASTLETON.

P. F. Hinchey and Company, Hydeville. Quarries. Mill stock only. Colors green, mottled and purple.
Penrhyn Slate Company, Hydeville. Quarries. Mill stock only. Hydeville Plant, Lake Bomoseen Plant, Scotch Hill Plant. Mottled, green and purple.
Hydeville Slate Works, Hydeville. Mill stock only. Mottled, green, purple.
John Jones Slate Company, Castleton. Quarry. Mill stock only. Mottled, purple.
Lake Shore Slate Company, West Castleton. Quarry. Mill stock only. Mottled and purple.

FAIR HAVEN.

Clark and Flanagan Slate Company. Quarries. Mill stock and roofing. Unfading green, purple, mottle, gray.
Durick, Keenan and Company. Quarry. Mill stock only. Mottled and purple.
Eureka Slate Company. Quarries. Roofing slate. Unfading green, mottled, purple.
Fair Haven Marble and Marbleized Slate Company. Quarry. Mottled purple, green.
Locke Slate Products Corporation. Mottled, green and mottled purple.
McNamarra Brothers Slate Company. Electrical slate only.
Mahar Brothers Slate Company. Quarries. Mill stock and roofing. Mottled, green and mottled purple.
Old English Slate Company. Quarry. Roofing. Mottled and purple. Office, Boston, Mass.
W. H. Pelkey Slate Company. Quarry. Roofing. Green.
Vermont Milling and Products Corporation. Ground slate only for roofing. Mill at Poultney; Office, Fair Haven.
A. B. Young Slate Company. Mill stock only.

POULTNEY.

Auld and Conger Company. Quarries in Vermont and Pennsylvania. Roofing. Weathering green, unfading green, sea green, purple, mottled.
Donelly and Pincus Slate Company. Quarries. Roofing. Unfading green, purple, mottled.
General Slate Company. Quarries. Roofing. Sea green, mottled, purple, gray.
United Slate Co. Roofing. Mottled.
Vendor Slate Company. Quarries. Roofing. Sea green, mottled, purple, gray and unfading.
Staso Milling Company. Ground slate only.
New York Consolidated Slate Company. Quarries. Roofing. Green, purple, unfading green, mottled.
F. C. Sheldon Slate Company. Quarries. Roofing. Purple and sea green.

WEST PAWLET.

Rising and Nelson Slate Company. Quarries. Roofing. Sea green.

WELLS.

O'Brien Brothers Slate Company. Quarries. Roofing. Purple and sea green.
Burdette and Hyatt. Quarries in Wells; Office in Whitehall, N. Y.

Norton Brothers Slate Company. Quarries in Vermont and Granville, N. Y.; Office in Granville, N. Y. Roofing. Green, purple, red.
O. W. Owens and Sons Slate Company. Quarries in Vermont and New York; Office in Granville, N. Y. Roofing. Green, purple, red.
Progressive Slate Company. Quarries in Vermont and New York; Office in Granville, N. Y. Purple, green, red.
F. C. Sheldon Slate Company. Quarries in Vermont; Office in Granville, N. Y. Roofing. Sea green.
Vermont Slate Company. Quarries in Vermont; Office in Granville, N. Y. Sea green, purple, red.
H. G. Williams Slate Company. Quarries in Vermont and New York; Office in Granville, N. Y. Roofing. Purple, red, green.

During the last few years the amount of slate shipped from Vermont has increased and is now not less than $4,000,000.

TALC AND SOAPSTONE.

As those who have read the Geological Reports immediately preceding this have noticed there has been considerable fluctuation in the amount of talc sold in Vermont during different years. Of late this has increased.

The companies producing this material in Vermont are as below:

LIST OF COMPANIES PRODUCING TALC.

American Mineral Company, Johnson.
Magnesia Talc Company, Waterbury.
Eastern Talc Company, Main Office, International Trust Co. Building, Boston, Mass. Mines, East Granville, Rochester.
Vermont Talc Company, Chester Depot.

SOAPSTONE.

American Soapstone Finish Company, Chester Depot.

LIME AND LIMESTONE.

Very little limestone to be used in building is sold in Vermont. Most of what is quarried is burned to quicklime. The value of such lime sold in the State amounts to not less than $500,000.

A list of Vermont companies that are now, or have recently produced lime are as follows:

LIST OF LIME KILNS IN VERMONT.

Amsden Gray Lime Company, Amsden. This company has been continuously active for many years. Of late, however, it has taken several important steps forward, involving considerable new machinery and will soon, if not already, be able to add largely to its output. Besides abundance of limestone, the company owns large tracts of woodland from which to obtain fuel and material for barrels.
Missisquoi Lime Works, Highgate Springs.
Fonda Lime Kilns, St. Albans.
Swanton Lime Works, Swanton.
Champlain Valley Corporation, Winooski.
Green Mountain Lime Company, New Haven Junction; Office, Worcester, Mass.
Brandon Lime and Marble Company, Leicester Junction.
Vermont Marble Company, Proctor.
Pownal Lime Company, Pownal; Office, 92 State St., Boston, Mass.

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