1931

Geology and Acid Intrusions of Marlboro Township, Vermont

Stanley Gordon Elder
Oberlin College

GEOLOGY AND ACID INTRUSIONS OF MARLBORO TOWNSHIP, VERMONT.

Hubbard make product formation

by

STANLEY C. ELDER

A Thesis in Geology

Submitted to the Department of Geology and

Geography in Partial Fulfillment of the

Requirements for the Degree of Master of Arts.

Oberlin College

June 1931

TABLE OF CONTENTS

LIST OF PLATES

PREFACE

It is the aim of this paper to examine the mineralization resulting from the intrusion of acid dikes and veins into the schists of Marlboro township, Vermont, and to give a brief account of the geology of the area.

The problem of mineralization in southern Vermont is one which has been treated very slightly and is one which is deserving of more study than it has received. This problem results from the presence of numerous acid igneous masses in all the formations of the region. Petrographic research in the igneous intrusions was done partially with the hope that the study would reveal minerals of economic importance and partially for the knowledge which the study would yield.

Grateful acknowledgement is due to Prof. G. D. Hubbard for suggesting this problem and for his untiring interest and assistance. Much appreciation is due also to Prof. A. A. L. Mathews, Mr. R. B. Frost, and Mr. Fred Foreman for valuable criticism and advice.

INTRODUCTION

Location and Area

During the summer of 1930 the Oberlin Geological Survey studied the geology of a portion of southern Vermont. This area is in Windham County and includes all of Marlboro township, except the portion west of the road extending north and south through West Marlboro and the portion north of latitude 42°55'N., the western third of Brattleboro township and the extreme southwest portion of Dummerston township. Within the region studied are two villages, Marlboro and West Marlboro, both located in Marlboro township in the west-central and extreme western parts of our area.

The section studied is about eight miles east and west and about six and a quarter miles north and south, or a total area of about fifty square miles. This area lies between Latitude 42°49'N. and 42°55'N. The eastern boundary is about 72°37'39"W. and the western boundary is about 72°46' 30"W.

Physiographically the region is located in the New England Division of the Older Appalachians.

The geologic location of the area is in the undifferentiated early Paleozoic rocks of New England.

Summary of Problem

The interpretation of the extensive mineralization and alteration which has resulted from acid intrusions is the main problem of this paper.

A most intricate problem of the region proved to be the interpretation of the structure. This was dependent entirely upon the relation between the original structure within the rocks and schistosity which was developed later. While the bedding and schistosity did not always agree, they were usually parallel. Interpretation of available data explains the structure satisfactorily by the presence of a homocline followed by an unconformity and by a fan-anticlinal fold.

The problem presented by the porphyroblastic phase in the Marlboro Schist was very difficult. Its origin is doubtful, because suggestions for either sedimentary or igneous origin are found in the field. Careful consideration of both sides of the question points to sedimentary origin as being the more probable.

PHYSIOGRAPHY

The general area is characterized by considerable irregularity of surface and has been reduced to slope, only the floors of the largest valleys approaching levelness. The summits of the hills often show a gradient of 5° to 20°. However, on middle slopes the rise is 6° to 34° with a tendency toward the steeper slope. On lower slopes the gradient becomes still steeper and ranges from 20° to 40°. The slope of valley floors is less than 1°. (See profile of cross-section opposite page 25, Plate 11). However, the relief is not great, averaging only about 600 feet. The elevations above sea level range from 560 feet northeast of Round Mountain in the valley of Whetstone Brook to 2060 feet at the crest of a hill one mile northeast of West Marlboro. Many of the hills are more than 1,500 feet above sea level and a few exceed 2,000 feet, but there is no marked accordance of summit levels.

The extreme upper parts of the hills appear to represent the remnant of an old topography rising above a plain of erosion which has been uplifted at least twice. Prof. G. D. Hubbard (1) has recognized two peneplanations in the vicinity

(1) Hubbard, G. D. - Geology of a Small Tract in South Central Vermont - 1923-1924 Report of the Vermont State Geologist - pp. 326-330.

of Readsboro and Wilmington. These observations are in harmony with those of our area. The drainage is dendritic in form and the rtreams flow eastward, northward and southward, but in a general easterly direction, forming a part of the Connecticut River drainage system. The valleys of the present streams are superimposed on broad mature pre-glacial valleys and essentially follow pre-glacial drainage. These valleys are V-shaped and, therefore, are youthful. There are two large lakes and one small lake in the region; they are the result of glacial drift unevenly deposited in pre-glacial valleys.

The entire region shows the effects of two cycles of erosion; an older pre-glacial cycle, in which the major features of the present topography were developed, produced the mature outlines of the upland surface. A younger post-glacial cycle has been eroding the glacial drift but has done little in dissecting the older mature surface.

The effects of glaciation are widespread, a large part of the area being unevenly covered with a heterogeneous mass of glacial drift. Two sets of glacial striae are present at two locations, the directions being N.19°E. at M-14 and b-6 and N.32°E. at T-25. Although this presents evidence for two periods of glaciation, two ages of drift are not found. In 1924 Prof. Hubbard (1) observed two ages of drift in the Readsboro region.

(1) Hubbard, G. D. - Op. Cit. - p. 330.

The corrosional effects of glaciation are most apparent on the bare ledges, both in the valleys and on the hills. Many of the outcrops are distinctly rounded and show a polished surface. In many cases huge boulders of country rock are found, which had been plucked from outcropping ledges on the sides of hills.

Ground moraine with an irregularly undulated surface is the most common glacial form in the region. Lateral moraines of well-defined continuity may be seen near the middle parts of ridges with a north-south trend. Kames are relatively uncommon, only one being found (y'-18); it is a small mound of assorted clays, sands, and gravels, the beds dipping down around the margin. Outwash plains with stratified gravels and sands are found at several places in the region (H-7-8, h-19, and m-15). The beds dip at varying angles toward the south, showing that the source of the materials was north of the outwash plain.

The Augur Hole is a broad U-shaped valley extending northeastward from Central Mountain and presents unique evidence of a valley glacier. Six terminal moraines within a distance of less than two miles may be counted in the most southerly part of the valley. They loop convexly toward the south across the valley. On both sides of the valley at an

altitude of 1060 feet are distinct and continuous terraces which contain unassorted drift; these features suggest lateral moraines. Covering most of the floor of the valley are stratified sands and clays with a horizontal attitude. It appears that a lake occupied the part of the valley in front of the glacier and sorted the sediments of the receding ice. The valley immediately west of the Augur Hole is notably different in appearance. It is characterized by many alluvial fans in contrast to the Augur Hole. Moreover, this valley is more V-shaped than the Augur Hole, showing that it was not occupied by a valley glacier. The evidence found in both valleys indicates that while the Augur Hole contained the valley glacier the other valley was relatively free of ice; this resulted in terminal and lateral moraines being deposited in the Augur Hole and alluvial fans in the valley to the west.

The lithology and structure of the formations have exerted a pronounced control over erosion. This is decidedly noticeable in the hornblende member of the Ames Hill Schist. This member outcrops with a general northeast-southwest trend and because it is very resistant to erosion forms a strike ridge, which is represented by a series of hills, Hill 1284, Round Mountain, Ginseng Hill, and Governors Mountain, the original continuous ridge having been divided into four separate hills by erosion.

These hills are "hogbacks", with the hornblende members dipping steeply toward the west.

Other strike ridges are found (t'-24) where the resistant hornblende strata of the Barrows Schist stand out above the surrounding topography. On the other hand, the siliceous strata of this formation tend to form depressions. In the other formations erosion has been differential, the hills being formed where the schists were most resistant.

DESCRIPTIVE GEOLOGY

Metamorphic Rocks of Sedimentary Origin

Cambrian (?)

Barrows Schist.- The oldest formation in the area is the Barrows Schist and extends westward beyond the limits of the area studied. Within the area there is a thickness of at least 3000 feet.

This formation outcrops east and southeast of Hogback Mountain in the area around West Marlboro and southwards to the edge of the township (u'-37). The contact to the east with the Central Mountain Schist is quite irregular except just north of West Marlboro where the contact swings west before continuing its general northerly course. This may be explained by a change in dip to the north within the Barrows Schist; this structure probably influenced the original dissection of the region, eroding away the less resistant overlying Central Mountain formation rather than eroding the more resistant Barrows. The contact of the two formations before erosion had taken place between hills 2060, 1936, and 1945, was more to the west. The contact, being gradational, is difficult to determine.

This formation is not consistent in composition or texture. The typical Barrows is a black, fine grained hornblendic schist with hornblende, quartz, black mica, and pyrite; the hornblende makes up a large percentage of the rock. There is a banded arrangement of the minerals giving the rock a gneissic appear-

ance, the quartz and hornblende being segregated in layers. Garnets are to be found occasionally near the contact with more siliceous strata. Occasionally the texture is rather coarse with larger crystals of hornblende and quartz. Texture is coarse and jointing is often developed to a great extent. It is very hard and resistant to weathering.

Interbedded with the typical hornblendic layers are more schistose layers which vary considerably in mineral content. These phases are much more siliceous than the typical Barrows and carry more mica of the black and green type. Hornblende is usually present making up a small percentage of the rock; often there is pyrite and sometimes garnet. Ordinarily this phase is coarse grained, although there are instances where the texture is medium to almost fine grained. The greater amount of mica gives it a definite schistosity. Jointing, although not common, is occasionally found. Although the formation as a whole received an equal amount of metamorphism, this phase shows much more minor folding, particularly in more micaceous horizons, than do the most siliceous and most hornblendic layers. Evidently the siliceous phase was more resistant to deformation. It weathers easily, having a light brown color on the weathered surface as the contained pyrite becomes oxidized. Because of its less resistance to weathering it erodes more quickly than the hornblende phase and forms the depressions between the ridges of the hornblende outcrops (t'-26). Between the hornblende and siliceous strata are transition zones. These phases vary in width from six to thirty feet, with an average of about sixteen feet.

Central Mountain Schist.- The name "Central Mountain" has been applied to this schist because Central Mountain is the main topographical feature within the area in which the formation outcrops.

The formation outcrops in a northeast-southwest direction with a maximum width of about three miles and a minimum width of a mile. An average width across the strike of two miles with an average dip to the east of 45° would give a thickness of 7000 feet to the formation.

The gradation from the Barrows Schist into the overlying Central Mountain Schist takes place through a coarse siliceous horizon. A gradation of greater extent marks the passing from the Central Mountain to the Marlboro Schist. This gradation is completed through four hundred feet, first quite siliceous and becoming very micaceous.

The typical Central Mountain Schist is a medium grained siliceous green mica schist with garnets, hornblende, chlinochlore, black brittle mica, sericite, and occasional pyrite and magnetite. Quartz is both in layers and intercalcated throughout the mass. Throughout the formation are lenses or stringers essentially of hornblende and quartz and occasionally of pyrite and biotite. These stringers vary from half an inch in width to a maximum of four feet. The larger ones are massive and may be of an igneous origin, since the strike of schistosity of the schist differs considerably from the strike of the stringer, whereas the smaller stringers and lenses, which have the same

strike as the schistosity and show bedding, may represent changes in the original sedimentation. Many of these stringers and lenses grade into the surrounding rock in a way that suggests sedimentary origin.

In the direction of the strike any horizon remains quite constant while across the strike there is often considerable change within a relatively short distance. Such changes are occasionally abrupt but are most often gradational. Some beds are micaceous, others are very siliceous, and still others have a predominance of hornblende. The hornblende and quartz layers offer more resistance to the agents of erosion while the normal and very micaceous phases are easily eroded. On the weathered surface the hornblende and quartz horizons stand out as much as a quarter of an inch above the adjacent layers. Efflorescense is common on the weathered surface of outcrops in which there is a small percentage of pyrite. Although garnets are more abundant in the western part of the formation, they are usually to be found as a result of contact metamorphism at the contacts of the quartz and pegmatite dikes. These dikes are common throughout the formation. Wherever garnets occur the schistosity is always found to bend around them.

Schistosity is well developed except in very siliceous phases. Several locations show severe crumpling, Hill 1906 (s'-t'-16-17) in particular. At this location the attitude of the beds varies greatly within a short distance; strikes range from N.45 E. to N.55 W. with the beds dipping in every quadrant of the compass. Such distortion is due to the presence of a ferro-magnesian mass of igneous

origin which is located on the western side of the hill and may underlie a part of it. This intrusion will be discussed more fully later. While the texture of the formation is ordinarily medium, it is sometimes very coarse and rarely fine grained. A jointing system is usually absent.

Marlboro Schist.- In the formation as a whole the direction of bedding is parallel to the schistosity, but there are several places where they meet at angles as high as 45°. The average strike is N.40°E. with a 60°dip to the southeast which, with a width of outcrop of two and a quarter miles, would give a thickness of approximately 9000 feet. Instead of a gradation into the adjoining Ames Hill Schist to the east, a sharp line of demarcation separated the two in all places where the contact was found.

The Marlboro Schist is the most variable formation in the region varying greatly within a short distance. In general there are four distinct phases in the formation, a gray siliceous schist in the extreme north, a green micaceous schist in the central part, a chlorite schist in the extreme south and hornblendic layers occurring in all three of the other phases.

The gray-blue siliceous schist of the north contains a large percentage of quartz. Micas present are chlorite, some biotite, and occasionally sericite. Small amounts of feldspar, magnetite, pyrite, and epidote are frequently present, except where the percentage of quartz is high. This phase is typically massive and is rarely jointed. Indications of this siliceous phase are found about

two and a half miles northeast of Marlboro. In the north it is consistently very siliceous except toward the contact with the Central Mountain where it becomes much more micaceous.

In the central part of the formation the green micaceous schist contains biotite, chlorite, quartz, and accessory amounts of sericite, pyrite, hornblende, garnet, and locally graphite. If any part of the formation could be called typical, it would be this phase, the description of it being applicable to the part outcropping around the town of Marlboro from which the formation is given its name. In micaceous horizons it is very schistose with good cleavage, and weathers easily, while where quartz is more abundant schistosity is not as well developed. Cleavage is poor and the rock is more resistant to weathering. This schist weathers to a dark brown and where pyrite is present, white lines of efflorescence due to the oxidation of the pyrite resulting in a sulphate of iron are to be seen. Jointing is as rare in this phase as in the siliceous phase to the north. Towards the western contact it becomes very siliceous and massive.

The chlorite schist in the south appears to contain chlorite with quartz, pyrite, hornblende, and occasionally biotite, graphite, garnet and magnetite. It is fine textured and is quite often phyllitic. It is not massive and has few joints. The weathered surface is usually a brownish green. This type of schist occurs from South Pond to the southern edge of the area.

The last phase is characteristic of the entire formation. It has a fine to coarse grained porphyroblastic structure with a matrix

dominantly of hornblende with quartz, epidote, and pyrite and with coarse porphyroblasts of an acid feldspar, saussurite, quartz and epidote. Occasionally there is an absence of blasts; however, a gradation takes place from the blastless variety into an horizon where blasts are abundant. Although the blasts are so numerous that in some cases they make up 75% to 80% of the rock, they are seldom arranged in any well defined order. Two types of hornblende are distinguished - black and green; the rocks containing the green hornblende show schistosity to a slight extent, while the black variety with no alligmment of crystals has no schistosity. This porphyroblastic phase occurs as lenses, varying greatly in size, throughout the surrounding schist; the schistosity nearly always bends around these lenses. They range in width from half an inch to fifty feet and in length from five feet to two hundred feet. In some cases a slight gradation from the normal schist to the porphyroblastic lenses has been noted, but such gradations are lacking as a rule. These lenses, where the bedding of the enclosing rock was apparent, corresponded in strike with the bedding of the schist. The structure is massive and usually has well developed jointing.

Ordovician (?)

The Ames Hill Schist is the youngest formation in the area studied and is treated as belonging to the Ordovician Period. This formation is correlated with the lower member of the Memphremagog Group, which Richardson (1) determines to be un-

(1) Richardson, C.H. - The Geology and Petrography of Reading, Cavendish, Baltimore, and Chester, Vermont 1927-1928 Report of the Vermont State Geologist - pp. 229-232.

questionably of Ordovician age. Since all the formations older than the Ames Hill Schist grade into one another, it appears reasonable to place them in the Upper Cambrian Period.

Ames Hill Schist.- The Ames Hill Schist receives its name from the hill upon whose east side the type section of the formation outcrops.

Because the Ames Hill Schist extends east of and beyond the area under consideration, the entire width cannot be definitely determined from present data. The strike of the formation varies from N.36° W. to N.74° E. with a tendency toward a northeast strike. In the extreme western portion the schist dips steeply to the southeast; within a mile from the contact with the Marlboro Schist the dip is vertical; and, throughout the eastern part of the area the dip is from 45° to the southwest to vertical. Since there is no evidence of any major disturbance which may have caused a repetition of beds, and considering a width of outcrop of three miles with steep dips, the thickness of the formation is without doubt more than 12,000 feet.

The typical Ames Hill Schist is garnetiferous, with biotite, quartz, pyrite, sericite, and disseminated graphite. The garnets vary from 1/16 to 1/4 of an inch in diameter. It has a lead-blue color and on fresh planes of schistosity it has a silvery luster. Schistosity is well developed and bends around the garnets, which are alligned in parallel planes. Ordinarily the schist has a slaty cleavage and is finely plicated and folded. The formation

is soft rather than resistant and weathers easily but uniformly to a reddish-brown color with white streaks of an iron sulphate where garnets and pyrite weather out. Occasionally there are phases in which there is a total absence of garnets, but in these cases there is an absence of quartz. Parallel to schistosity are occasional quartz stringers, lenticular in shape, and sometimes showing pinch and swell structure.

Interbedded with the typical schist are numerous lenses of even, medium grained quartz cemented by calcite and a small amount of iron carbonate. The unweathered surface is slate gray in color while the weathered surface is reddish brown. It weathers inwardly to a core which seems to be impervious to waters percolating downward, leaving very porous residual material surrounding the core. These layers vary in thickness from six inches to six feet, and in length appear to be continuous for several hundred feet with the strike of the formation.

The name of Whetstone Schist has been applied to the type of rock directly east of the typical Ames Hill and west and east of the lens of the Round Mountain Schist. But, it is the opinion of the writer that the Ames Hill Schist, the Whetstone Schist, and the Round Mountain Schist should all be included under the name of the Ames Hill Schist, because there is not enough distinction between the Ames Hill Schist and the Whetstone Schist to warrant calling them separate formations, and because the Round Mountain Schist is only a lens within the Ames Hill Schist; therefore, the Whetstone

and the Round Mountain Schists will be treated as being phases of the Ames Hill Schist.

The Whetstone phase adjoining the typical Ames Hill appears to be gradational. The change is so gradual that it was very difficult to determine in the field just where the contact should be placed. This variety is typically a greenish blue garnetiferous schist, finely plicated, with garnets, disseminated graphite, biotite and quartz. The quartz is arranged in long narrow bands. Locally there is pyrrhotite, hornblende, pyrite, and chlorite. Within this phase are siliceous lenses from slate to gray in color, with a very high percentage of medium to fine grained quartz which is cemented with calcium carbonate; the presence of iron carbonate gives the weathered surface a dark red color. As in the typical Ames Hill, these siliceous lenses weather inward to a central core. Occasionally there are almost quartzitic horizons, lacking in garnets, within the schist, but which have a definite schistose structure. The gradation into Round Mountain Schist takes place within twenty feet.

The Round Mountain member is highly hornblendic. The principal minerals are hornblende and quartz with about 75% to 95% of the former. Accessory minerals when present are actinolite, biotite, magnetite, and pyrite. The structure is banded with the quartz arranged in small thin layers. This schist is extremely resistant to weathering, forming the topographic highs of the immediate region. Jointing is often well developed. Within this phase, and near the crests of Round Mountain and Ginseng Hill, are

light gray lenses six or seven inches wide which are highly quartzose, but also have chlorite, hornblende, and biotite, all of which are arranged in thin layers. Whether these lenses are continuous across the valley was not determined. The Round Mountain phase disappears at i-14-15 and does not reappear north of this location.

Sedimentary Rocks

Pleistocene

Covering the greater part of the area is a mantle of glacial drift, which has been unconformably deposited upon the surface. Ever since the glacier withdrew, the drift has tended to become more compact and consolidated. This drift is composed of a heterogeneous mass of boulders of all sizes, gravels, clays and sands, although sometimes there has been a sorting of the materials by water from the receding glacier. The thickness varies from nothing, where the bedrock is bare, to one hundred feet or more, where the drift has filled pre-glacial valleys.

Recent

Unconformably upon the glacial drift are alluvial deposits which have formed since the retreat of the glacier. They are found on the small flood plains, on the beds of the present streams, and at the foot of gullies on the sides of slopes; these deposits consist of clays, sands, and gravels, which are stratified, and therefore, have been water-laid, but which are unconsolidated.

BASIC IGNEOUS ROCKS

Upper Cambrian (?)

Basic igneous activity probably took place at the close of the Cambrian Period contemporaneous with the Green Mountain Disturbance for neither in the Marlboro area nor in the regions to the north (1) do such types of igneous rock occur in any formations younger than the Cambrian. In Massachusetts (2) are similar rocks which occur only in the equivalents of the Cambrian formations.

So far as known, there is only one mass of a basic igneous rock in the area, which is located at s'-17 within the Central Mountain Schist. A central core of coarsely crystalline, dark green hornblende with small amounts of actinolite, pyrrhotite, quartz, and secondary sericite stands prominently above the flood plain of a nearby stream. Around the core is a layer of crystalline serpentine, which has altered from hornblende. On one side of the core in the stream bed is found fibrous serpentine, talc, and ankerite. The entire outcrop is coarse grained and hornblendic in the center with a gradual transition to the serpentine on the outer rim. The present constituents are the result of metamorphism and hydrothermal alteration of the original mass. The outcrop has an oval form about 40 feet in diameter. It may extend under Hill 1906, which shows severe crumpling.

(1) Perry, E. L., - Geology of Bridgewater and Plymouth - 1927-1928 Report of the Vermont State Geologist -pp.41-42.
(2) Emerson, B. K., - Geology of Massachusetts and Rhode Island - U. S. G. S. Bulletin 597 - pp. 156-157.

ACID IGNEOUS ROCKS

The age of the acid dikes, which appear to be of two periods of intrusion, is difficult to determine. Metamorphosed and unmetamorphosed dikes occur in the Cambrian and Ordovician formations and are, therefore, of two ages. It seems reasonable to associate the unmetamorphosed dikes with the Appalachian Revolution and the metamorphosed ones with an earlier period of intrusion.

Of the acid igneous rocks, two distinct kinds occur in the region - quartz dikes and pegmatite dikes, both of which are found in all the formations. The quartz dikes are usually intruded in the planes of schistosity of the country rock, but where the schist is massive they are as likely to cut across as to follow the schistosity. They vary in size from minute veinlets up to six feet in width and seventy-five feet in length. In many cases the quartz has undergone granulation, having been involved in the regional metamorphism. The pegmatites are found to follow and to cross the schistosity in the same way as the quartz veins. The pegmatite veins are composed of albite, orthoclase, and quartz, and vary in size from six inches to three feet in width and from four feet to thirty feet in length. It is known that gradations do take place from the pegmatite dikes into quartz veins; however, no instances of such a gradation were observed in the area. Both types of acid igneous rocks have caused the formation of secondary minerals along the contacts with the enclosing schists; the products of mineralization will be considered later.

CORRELATION OF THE FORMATIONS

Correlation of the section in the Marlboro area with those of other nearby regions is made on the basis of lithology, unconformities, and stratigraphic succession. The use of fossils is impossible since none were recognized in any of the formations.

The accompanying correlation map (Plate 9) shows a basis for correlating Emerson's formations in Massachusetts with those in the Marlboro region. Since Emerson's work in Massachusetts came within six miles of the area under consideration, it is believed that exact interpolation can be made of the contacts between the two regions by projecting the known contacts of the formations along their general strikes.

Interpolation of the contacts between the area of Perry's study to the north and those of the Marlboro region is more difficult, since there is a distance of forty-six miles between the two locations. The mapped areas are drawn to scale, and, while the unmapped portions are exaggerated north and south, the general trend of the formations may be traced.

Since Perry has correlated his formations of Bridgewater and Plymouth Townships with those of Richardson (1) and since the areas studied by the latter lie northeast and northwest of the Marlboro area, only the region studied by Perry is mapped for northern correlation.

(1) Richardson has studied in Reading, Cavendish, Baltimore, Chester, Bethel, Barnard, Pomfret, Woodstock, Springfield, Grafton, and Rockingham Townships.

The correlation table (Plate 10) shows the comparative descriptions which characterize the formations and offer further reasons for the correlation of similar formations.

The names of the formations as determined in the Marlboro region are used instead of the formation names of Emerson, Richardson or Perry, because no type section has been established in Vermont.

Note - Data for the correlation of the formations are taken from the following sources:

1. Emerson, B. K., - Geology of Massachusetts and Rhode Island - U.S.G.S. Bulletin 597 - pp. 43-47; Geological Map.
2. Hubbard, G. D., - Geology of a Small Tract in South Central Vermont - 1923-1924 Report of the Vermont State Geologist - pp. 288-289.
3. Perry, E. L., - Geology of Bridgewater and Plymouth - 1927-1928 Report of the Vermont State Geologist - pp.29-30; 32-36.
4. Richardson, C. W., - The Terranes of Bethel, Vermont - 1923-1924 Report of the Vermont State Geologist - pp. 82-85.
- Geology and Petrology of Barnard, Pomfret and Woodstock - 1925-1926 Report of the Vermont State Geologist - p. 137; 150-151.
- Geology and Petrography of Reading, Cavendish, Baltimore, and Chester, Vt. - 1927-1928 Report of the Vermont State Geologist - pp. 221-222; 224-225; 227-229.

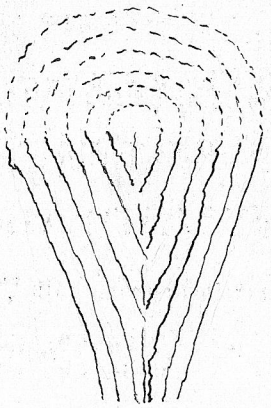
STRUCTURAL GEOLOGY

From the accompanying structure map and cross-section (Plates 11 and 12), it may be seen that the dips in the western and central portion of the area are essentially toward the east. Since Pumpelly (1) ascribes anticlinal structure to the Green Mountains, the structure of the Marlboro region is probably a part of the eastern flank of this anticline. Because of the consistency of dip, it is certain that the formations of the central and west portions of the Marlboro area have a homoclinal structure dipping to the east. Superimposed upon the major structure of the area are small wrinkles. Such folds do not extend throughout the length of the formation but are local and may disappear within a short distance. At q'-36 is a small anticline with a northeast-southwest trend having moderate dips. At r'-33 is a small over-turned anticline, which shows older layers overlying younger beds.

In the eastern part of the region where the Ames Hill Schist outcrops, the dips are for the most part to the west, except for a strip of about a mile wide immediately east of the contact with the Marlboro Schist, where the beds dip steeply toward the east, become progressively steeper, and eventually become vertical. The interpretation of such attitudes of the beds is a fan-anticlinal fold with its axis about a mile east of the Ames Hill -

(1) Pumpelly, Raphael; Wolff, J.E; Dale, T.N. -
Geology of the Green Mountains in Massachusetts -
U.S.G.S. Monograph 23 - pp. 5-9.

Marlboro contact. The fold has been squeezed at the bottom as shown in the accompanying illustration.



Fan-anticline

Interpretation of the fan-anticlinal fold of the Ames Hill Schist is substantiated by Richardson's (1) interpretation of the structure of the same formation in Springfield Township to the north as a series of closely folded anticlines and synclines.

In the region of Hill 1906 (s'-16) the beds have been severely contorted, due probably to a period of igneous activity which intruded the ferro-magnesian mass at the foot of the hill. Across the southern flank of the hill are strikes varying from N.40° W. to N.24° E. with dips to both east and west resulting in a series of small synclines and anticlines. Even on the top of the hill are complex contortions.

In all the formations are horizons which are very plicated. These plications are usually of small magnitude and occur in very

(1) Richardson, C.H., - The Areal and Structural Geology of Springfield, Vermont - 1929-1930 Report of the Vermont State Geologist - p. 204

schistose and massive structures. They are so common in the schistose structures that no mention will be made of locations. They occur in the massive hornblende schists at v'-29 and j-17.

In the area as a whole the strikes of the beds are generally northeast-southwest with local variations. The average strike is N.25°-30°E. In the extreme eastern part of the area, beds with a northwest strike change abruptly to a northeast strike. Locally, the strikes of beds change from 5° to 40° as they swing around acid dikes.

There is known to be only one major fault in the area (g-29), where a block of the Round Mountain member lies within the Whetstone member of the Ames Hill Schist. One side of the mass is characterized by a zone of brecciation, in which is a series of minor faults which terminate small folds and plications of the hornblende schist. This mass is only five feet wide and about two hundred yards long. Since the main mass of the hornblende schist outcrops on the top of the hill and since the displaced block apparently slipped down, the fault is classified as a normal fault.

A number of displacements of only a few inches occur in nearly all the formations. At F-16, an outcrop of the Central Mountain Schist shows two displacements of four inches and two inches respectively and a slight drag in the beds adjacent to the displacements. At S-14, a quartz stringer has been displaced several inches.

MINERALIZATION ALONG ACID DIKES

Review of Literature

Very little literature has been published on the mineralization of acid dikes in Vermont. In 1922 Harriet G. Bray and Alden H. Emery (1) wrote a paper entitled, "Mineralization Along the Dikes of Southern Vermont." The center of their field of activity was in Wilmington located nine miles west of the center of the area under consideration. This is the only published article bearing directly on the mineralization of dikes in this region. It, therefore, serves as a valuable means of comparing the products of mineralization in Wilmington with those in Marlboro Township.

G. O. Smith (2) has written a report on the quartz veins in Maine and Vermont, which discusses chiefly the economic values of these veins, but not their mineralogical occurrence.

Materials and Methods

While the area was being studied, data on the occurrence and specimens of the acid dikes were collected. A megascopic study was first made to ascertain which specimens should be used in gathering data for the problem. Fifty thin-sections were made of the selected specimens for microscopic study.

In the laboratory, a petrographic study was made of the thin-sections to determine the minerals of the dikes, their paragenesis, and the alteration of the intruded rocks along

(1) Bray, H.G., and Emery, A.H.,-Mineralization Along the Dikes of Southern Vermont - The Ohio Journal of Science, Vol. 23, No. 2, March 1923, pp. 83-88.
(2) Smith, G.O., - Quartz Veins in Maine and Vermont - U.S.G.S. Bulletin 225 - pp. 85-88.

the contacts of the dikes.

Account of Investigation

The acid intrusions are coarse crystalline rocks, in which quartz and feldspar are the essential minerals. They vary in relative percentages of quartz and feldspar from veins of entirely quartz to pegmatite veins in which the amount of quartz is small.

A specific account of the petrographic study of the slides presenting both typical and unusual features is necessary to show the relation of the minerals to the intrusions and to the country rock.

Pegmatite dike in the Barrows Schist.- A specimen from the edge of a pegmatite dike includes the contact with the Barrows Schist (r'-15) and mineralization products (1) and recrystallized minerals (2). Introduced minerals are muscovite, albite, orthoclase, and quartz. Small inclusions of muscovite are found within crystals of quartz and feldspar, and crystals of orthoclase occur within quartz. This is evidence that the order of crystallization was muscovite - feldspar - quartz. Only a portion of the quartz has euhedral form, most of it occupying the spaces between the crystals of feldspar. A large

(1) By mineralization is meant the development of minerals in and adjacent to an acidic intrusion due to accompanying gases or mineralizers.
(2) Those minerals which are essential or accessory to the enclosing schist and which are the result of pressure and hydrothermal activity are referred to as recrystallized minerals.

part of the feldspar has been hydrothermally altered to sericite.

Large crystals of hornblende project irregularly from the wall of the intrusion into the zone of mineralization. The hornblende is known to be recrystallized since it is a dominant mineral of the enclosing schist, recrystallization being due to the heat and gases of the intrusion which hydrothermally altered the country rock.

Pegmatite dike in the Central Mountain Schist.- A sample of the contact of a pegmatite dike with the Central Mountain Schist (y'-22) contains crystals of feldspar and quartz, and large flakes of black and green mica in the zone of recrystallized minerals. The feldspar crystals are orthoclase whose diameters vary from 0.2 mm. to 3.5 mm. Quartz, 0.5 mm. to 4.0 mm., occurs in ideomorphic crystals, and fills the interstices between the feldspar; all of the quartz shows strain extinction. Small inclusions of magnetite characterize the orthoclase and the quartz. These inclusions are generally arranged in lineer groupings which sometimes curve and cross each other. The relation of the magnetite inclusions to the feldspar and quartz is evidence that the magnetite was the first to crystallize. Small flakes of muscovite occur in an indefinite arrangement throughout the slide.

Pegmatite intrusion in the Ames Hill Schist.- Loose rocks of a pegmatite intrusion, occurring within the Ames Hill Schist (1-15), are believed to be near the outcropping intrusion. The hand speci-

men consists chiefly of pegmatite minerals and a thin contact zone of country rock. Blue tourmaline is shown in the sample but is not included in the thin-section. The crystals of albite and oligoclase vary from 3.0 mm. to 6.0 mm. in diameter. Large flakes of muscovite characterize the specimen. Quartz fills the interstices between the feldspar and muscovite. Small grains of magnetite occur as inclusions within the feldspar, mica, and quartz, and therefore were recrystallized first. Some limonite is present due to the weathering of the magnetite.

Pegmatite dike in the Marlboro Schist.- Microscopic study of the contact of a pegmatite dike and the Marlboro Schist (M-39) shows that orthoclase, quartz, rutile, and magnetite are the introduced minerals. Rutile and magnetite are associated with each other, and occur within and between the contacts of large euhedral crystals of quartz and feldspar. This quartz is characterized by strain extinction, and shows that it has been subjected to insufficient strain to produce granulation, but great enough to give anomalous optical effects.

Hornblende and quartz border on introduced minerals and are recognized as being recrystallized. The hornblende is arranged in a network and is associated with even grained recrystallized quartz. In this instance the quartz shows normal extinction.

Pegmatite dike in the Marlboro Schist.- The sample of a pegmatite dike in the Marlboro Schist (T-17) contains a thin contact with the country rock. The essential minerals of the dike are feldspar and quartz which occur in large crystals. A feldspar

crystal having a length of 2.6 cm. was found. The thin-section reveals the zoning of albite around an initial nucleus of orthoclase. All of the feldspar is in large crystals from 4.0 mm. to 6.0 mm. in diameter, and much of it has been sericitized. Quartz fills the interstices between the feldspar and shows undulatory extinction. Small flakes of muscovite are arranged irregularly in the quartz and feldspar.

Chlorite and zoisite are the only recrystallized minerals and are associated with each other. They occur in a zone adjoining the pegmatite minerals and are the results of hydrothermally altered and unknown minerals of the country rock.

At the same location (T-17), and within five feet of the sample just described, another specimen of the contact of the intrusion with the Marlboro Schist shows still other features. The introduced minerals are orthoclase, albite, quartz, magnetite, biotite, rutile, and topaz. The feldspars have been partially sericitized; the alteration probably immediately followed the intrusion of the dike. The crystals of feldspar vary from 0.2 mm. to 6.0 mm. in diameter. The spaces between the feldspar crystals are filled with quartz. The biotite is irregularly associated with quartz and feldspar. Magnetite, 0.005 mm. to 0.04 mm. in diameter, and rutile, 0.01 mm. to 0.05 mm. in diameter, are enclosed in crystals of biotite, feldspar and quartz.

Chlorite is the only recrystallized mineral because it occurs alone outside the zone of mineralization. In this case,

the chlorite is the result of hydrothermal activity, and the parent mineral is unknown, but was likely actinolite or some other monoclinic amphibole.

Pegmatite intrusion in the Central Mountain Schist.- A sample containing the contact of a pegmatite intrusion with the Central Mountain Schist (C-22) shows plates of ilmenite and large flakes of biotite cutting through large crystals of feldspar and quartz. The thin-section shows that the introduced minerals are quartz, orthoclase, microcline, biotite, and ilmenite. Ilmenite was the first mineral to crystallize, because some splinters occur within biotite and others are partially enclosed by feldspar. A part of the feldspar has been altered to sericite, and the quartz is characterized by anomalous extinction and by minute indeterminable inclusions whose index of refraction is lower than that of quartz.

The recrystallized minerals are biotite, chlorite, garnet, muscovite, and epidote. The chlorite is associated with and appears to be altered from recrystallized biotite. The chlorite is secondary because it retains the structure of the biotite. Pleochroic halos characterize the recrystalled biotite. The muscovite is found to be irregularly arranged in small flakes. Microscopic garnets and rounded grains of epidote are common within the area occupied by recrystallized minerals.

Acid vein in the Marlboro Schist.- A specimen of an acid vein near the contact in the Marlboro Schist (P-5) contains needles of black tourmaline which pierce quartz crystals. Chlorite near the wall of the intrusion surrounds long tourmaline crystals. Part of the tourmaline has been altered to chlorite by hydrothemal solutions. The presence of the tourmaline shows that pneumatolytic metamorphism of the country rock took place along the wall of the intrusion. In this process the united effects of heat and intrusive gases, including water vapor and boron, combined with the country rock to form tourmaline. Only small amounts of orthoclase and microcline are present, and they are entirely enclosed by large euhedral crystals of quartz. Occasional flakes of muscovite and biotite and small irregular grains of magnetite are present throughout the quartz and feldspar.

Pegmatite intrusion in the Marlboro Schist.- A sample from the edge of a pegmatite intrusion in the Marlboro Schist (J-39) shows inclusion of chlorite within the feldspar. Microscopic crystals of tourmaline are enclosed in orthoclase crystals ranging from 2.0 mm. to 4.0 mm. in diameter. The orthoclase has a peculiar arrangement of minute inclusions. These inclusions are arranged in linear groups which intersect almost at right angles, forming parallelograms. Small flakes of biotite are included within the orthoclase and were, therefore, introduced with the intrusion. Parts of the edges of the biotite have altered to chlorite, still

leaving the original structure of the biotite. The relations between the minerals show that the feldspar crystallized after the tourmaline and the biotite.

Acid intrusion in the Marlboro Schist.- A specimen of an acid intrusion within the Marlboro Schist (T-14), taken from within the intrusion shows a banded arrangement of light and dark minerals on one side and chlorite and radiating slivers of actinolite on the other side, with an uneven line of contact between the two. Quartz and orthoclase are crushed to granules 0.01 mm. to 0.07 mm. in diameter, the quartz grains being the smaller. Fragments of actinolite, partially altered to chlorite, are common. Small grains of magnetite, epidote, and zoisite occur throughout the slide. Muscovite is developed in large sheets, 0.05 mm. to 0.10 mm. by 1.65 mm., often including small grains of the other minerals. There is a parallel arrangement of all these minerals, and this is evidence that the intrusion preceded regional metamorphism. Intense pressure must have been necessary to bring about such complete granulation and allignment of the minerals.

Recrystallization in the Central Mountain Schist.- A sample of recrystallization just outside the zone of intrusion in the Central Mountain Schist (C-22) contains large cubes of pyrite with medium to coarse grained quartz and mica. The micas and pyrite appear to have a parallel arrangement. The pyrite crystals vary from microscopic size to 0.65 cm. in diameter and are usually sur-

rounded by rims of limonite. Although broad leaves of muscovite and biotite are often irregularly intertwined, they have a parallel alligment. Large masses of chlorite occur throughout the slide and have no relation to any other mineral. Since chlorite is an accessory mineral of the schist, its immediate origin must be laid to the fact that it already existed in the schist before the intrusion occurred. Between and projecting into the leaves of mica are uniform grains of quartz which show no strain extinction. This is evidence that the quartz has been recrystallized. Magnetite of microscopic size is found as inclusions within the other minerals in the slide.

Unusual development of garnets and magnetite in the Marlboro Schist.- A specimen from the Marlboro Schist (H-33), probably, since the intrusive body was not present, close to the contact of an intrusion, shows a peculiar arrangement of garnets. Garnets, 0.65 mm. in diameter, in a fine grained chloritic matrix, are arranged in either straight or curved long stringers which are occasionally cut by thin quartz veins. Microscopic study shows shattered garnets, which have unstrained, recrystallized quartz along some fracture planes, and limonide stain along others. Magnetite occurs as cubes, pyritohedrons, and aggregates within the garnets. Tests for index of refraction show that these garnets are of the andradite type. The matrix of the garnets is composed of chlorite, quartz, biotite, and muscovite. Chlorite is present as

an essential mineral of the schist in which the intrusion occurred. The quartz of the matrix is in small uniform grains which show undulatory extinction. The biotite and muscovite are present in small flakes. The study of the thin-section yielded no clue as to the explanation of the remarkable appearance of the garnets.

At the same location (H-33), and within ten feet of the feature just described, octahedrons of magnetite, 0.32 cm. along the c-axis, occur in a fine grained green matrix. Microscopic study reveals that the matrix consists of chlorite, garnet, quartz and biotite. The garnets are irregular in outline, shattered, and have limonide stains on the fracture planes. The quartz is even grained and contains small indeterminable inclusions whose index of refraction is less than that of quartz. Biotite occurs only in small flakes. Evidence to explain the occurrence of the magnetite is also lacking.

Quartz vein in the Ames Hill Schist.- A sample of a quartz vein and its contact with the Ames Hill Schist (i-25) contains an imperfect crystal of cyanite, which is imbedded in the quartz. This vein has without question been subject to pressure of a vectorial type. The presence of the cyanite proves that it was formed under stress conditions, because it is typically a stress mineral. The quartz of the vein is granulated and shows strain extinction. Since silica was the only introduced mineral, a portion of it must have combined with aluminum oxide in the country rock to form cyanite ($SiO_2 . Al_2O_3$).

The recrystallized minerals are zircon, biotite, magnetite, muscovite, garnet, and quartz, all of which have a banded arrangement. Grains of zircon, 0.01 mm. to 0.03 mm. in diameter, occur within the leaves of biotite and are enclosed by pleochroic halos. There are perfect dodecahedral garnets varying in diameter from 0.13 mm. to 0.25 mm. The recrystallized quartz is characterized by normal extinction. Specks of magnetite have an irregular distribution throughout the biotite, muscovite, and quartz.

Discussion of Results

The results of this research are in general agreement with those reported by Bray and Emery (1). The same suite of minerals, with a few exceptions, is noted.

The essential minerals of the acid intrusions in the Marlboro region, were likewise found in the Wilmington area.

The scarcity of muscovite and the relative abundance of other micas is unique. The occurrence of both accessory and recrystallized minerals, such as tourmaline, hornblende, pyrite, ilmenite, magnetite, epidote, and penninite, is common to both reports.

Pyrite is rare, and occurs only as a recrystallized mineral; it is absent within the acid dikes of Marlboro Township, while Bray and Emery report it as being common.

This study reveals the presence of rutile, zircon, topaz and garnet, which Bray and Emery do not report. Although these minerals are not important, they help to show that the products

(1) Bray, H.G., and Emery, A.H., - Op. Cit. - pp. 86-88.

of mineralization in the two areas, although similar in several aspects, are not identical.

In 1861, A. D. Hager (2) reported the presence of gold in the alluvium of Marlboro Township. Since gold is known to occur commonly in quartz dikes, and since the usual origin of gold in alluvium is considered quartz dikes at an altitude higher than the stream valley, traces of it should be found, but no evidence of the presence of gold was revealed.

Conclusions

1. Essential minerals of the veins and dikes are orthoclase, microcline, albite, oligoclase, and quartz.

2. Accessory minerals of the intrusions are magnetite, ilmenite, muscovite, biotite, tourmaline, topaz, zircon, and rutile.

3. The order of crystallization was basic minerals - muscovite - feldspars - quartz.

4. The volatile mineralizers contained in the intrusives, as deduced from the minerals subsequently formed were zirconium, boron, fluorine, titanium, water vapor, oxygen, and carbon dioxide.

5. The products of recrystallization are chlorite, biotite, hornblende, penninite, magnetite, epidote, zoisite, garnet, zircon, muscovite, and pyrite. These products have depended largely upon the minerals composing the enclosing rock.

6. Some intrusions have preceded and others have either accompanied or followed the latest regional metamorphism.

7. There are no minerals of economic importance.

(2) Hager, A. D., - Report of the Geology of Vermont - Vol. 2, 1861 - Geological Map.

HISTORICAL NOTES

Origin of the Country Rocks

J. D. Trueman (1) has established certain criteria for determining the sedimentary origin of metamorphic rocks. Results obtained from the application of these criteria to the study of the formations show that they are sedimentary, except the pophyroblastic phase of the Marlboro Schist.

These may be summarized as follows:

1. The original bedding planes are preserved.

2. There is a persistency of composition along the same bed.

3. Abrupt change in texture and composition occurs across the beds.

4. Quartz constitutes 50% to 55% of the formations.

5. Graphite is evenly distributed in the Ames Hill and Marlboro Schists.

The origin of the porphyroblastic phase of the Marlboro Schist is a difficult problem, because there is evidence for both igneous and sedimentary origin. Arguments in favor of an igneous origin are as follows:

1. The character of the outcrops is lenticular.

2. All outcrops show massive characteristics.

3. The strike of schistosity tends to cross the strike of the lenses at an acute angle.

(1) Trueman, J.D., - The Value of Certain Criteria for the Determination of the Origin of Foliated Crystalline Rocks - Journal of Geology, Vol. 20, 1912 - pp. 236-244.

4. The porphyroblastic outcrops suggest apophyses of a basic igneous rock in the schist.

5. The enclosing schist appears to be spread apart, so that schistosity bends around the lenses.

6. The jointing system is composed of rhomboidal blocks.

7. Saussurite, usually derived from basic igneous feldspars, occurs in the blasts.

The following arguments for sedimentary origin appear to outweigh those for igneous origin:

1. The lenses occur only in the Marlboro Schist. If they are of igneous origin, similar lenses should have been found in the other formations.

2. Bedding planes occur in the lenses at J-37, O-14, and S-25. In the region of S-15 the porphyroblastic phase appears to be interbedded with a green siliceous schist.

3. There is an absence of contact metamorphism between the lenses and the surrounding schists. On the contrary, a gradual change in mineralogical composition takes place from the enclosing schist into the lenses. In any one lens there may be a wide variation in the distribution of the blasts. At S-16, coarse grained bands with many blasts alternate with fine grained bands with very few blasts.

The talc and hornblende mass, which occurs in the Central Mountain Schist, is, without doubt, of igneous origin. "Ankerite", according to Perry (1) "is typically a product of the metamorphism

(1) Perry, E. L., - Op. Cit. p. 39.

of igneous rocks." Serpentine with the association of ankerite is almost indisputable evidence of igneous origin.

Metamorphism

The schistose structures in the rocks of Marlboro Township show that recrystallization and rock flowage have taken place. The parallel relation of the strike and dip of schistosity to the strike and dip of the bedding is evidence that folding and regional metamorphism were contemporaneous. The only disturbance which could have caused this deformation was the Appalachian Revolution which is recognized as the major disturbance in New England. This is evidence against the theory of Wigglesworth (1) who ascribes enough deformation during the Taconic Disturbance to develop schistose structures. If folding had occurred in the Ordovician Period, as Wigglesworth infers, the strike of schistosity developed at the end of the Permian would have had an anguler relation to the strike of the bedding. Only locally is the strike of schistosity different from the strike of the bedding.

The Green Mountain, the Taconic, and the Acadian Disturbances certainly caused the New England rocks to be uplifted and, likely, resulted in further consolidation of the arenaceous shales and argillaceous sandstones.

The micas of the schists show that their basal cleavage is oriented at right angles to the direction in which pressure must have been applied, and the hornblende shows a tendency toward the

(1) Wigglesworth, Edward, - The Serpentines of Vermont - 1915-1916 Report of the Vermont State Geologist - p. 289.

parallelism of the longer crystallographic axes. The presence of granulated feldspar with recrystallized quartz indicates that great pressure must have been exerted. It has already been proved that no disturbance previous to the Appalachian Revolution could have resulted in more than mere uplift of the rocks. Therefore, the disturbance which resulted in the schistose structures of the formations of the Marlboro area was the Appalachian Revolution.

The presence of garnets and unoriented biotite and hornblende shows that pressure was still great after rock flowage had ceased and led to a state of mass-static metamorphism, causing the adjustment of these minerals to the pressure.

The occurrence of mica flakes in dodecahedral forms as pseudomorphs after garnet, notably at K-18, is evidence that garnets are unstable in the zone of katamorphism and that retrogressive metamorphism is taking place. Garnet is typically a high pressure mineral and breaks down to minerals which are stable in the zone of katamorphism.

ECONOMIC GEOLOGY

Unfortunately, minerals of economic importance are very scarce in the entire region. Although the many quartz and pegmatite veins would lead one to expect silver and gold, these minerals are not found. The deposit of talc on the southwest side of Hill 1906 and the many pegmatite dikes, of which feldspar is a valuable mineral, are not large enough to be of economic importance. Glacial gravels and sands are exploited extensively for road and building materials. The soil is most important to the inhabitants of the region because it is suitable for agricultural pursuits. Since many of the slopes are heavily timbered, lumber is an important resource.

BIBLIOGRAPHY

1. Bray, H.C., and Emery, A.H., - Mineralization Along the Dikes of Southern Vermont - The Ohio Journal of Science, Vol. 23, No. 2, March 1923.

2. Emerson, B.K., - Geology of Massachusetts and Rhode Island - U. S. G. S. Bulletin 597.

3. Hager, A.D., Report of the Geology of Vermont - Vol. 2, 1861.

4. Hubbard, G.D., - Geology of a Small Tract in South Central Vermont - 1923-1924 Report of the Vermont State Geologist.

5. Perry, E.L., - Geology of Bridgewater and Plymouth - 1927-1928 Report of the Vermont State Geologist.

6. Pumpelly, Raphael; Wolff, J.E.; Dale, T.N., - Geology of the Green Mountains in Massachusetts - U.S.G.S. Monograph 23.

7. Richardson, C.H., - The Terranes of Bethel, Vt. - 1923-1924 Report of the Vermont State Geologist.

8. Richardson, C.H., - Geology and Petrology of Barnard, Pomfret, and Woodstock, Vt., - 1925-1926 Report of the Vermont State Geologist.

9. Richardson, C.H., - Geology and Petrography of Reading, Cavendish, Baltimore, and Chester, Vt. - 1927-1928 Report of the Vermont State Geologist.

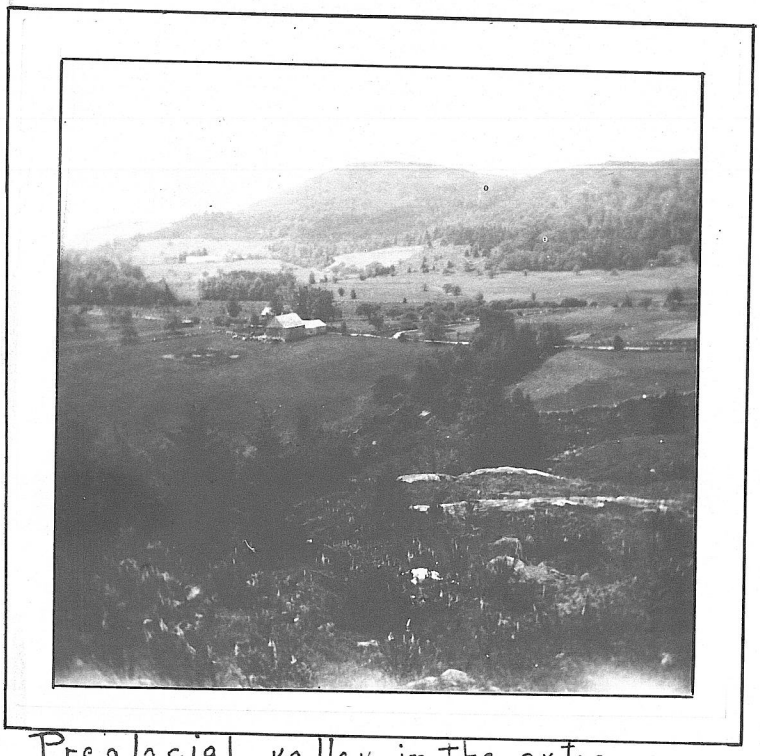
10. Richardson, C.H., - The Areal and Structural Geology of Springfield, Vt. -,1929-1930 Report of the Vermont State Geologist.

11. Smith, G.O., - Quartz Veins in Maine and Vermont - U.S.G.S. Bulletin 225.

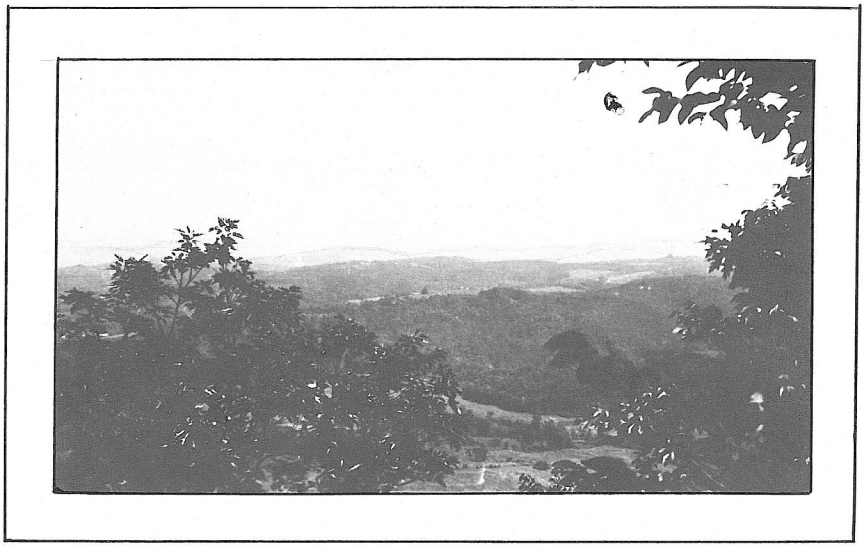
12. Trueman, J.D., - The Value of Certain Criteria for the Determination of the Origin of Foliated Crystalline Rocks - Journal of Geology, Vol. 20, 1912.

13. Wigglesworth, Edward, - The Serpentines of Vermont - 1915-1916 Report of the Vermont State Geologist.

Plate 1.

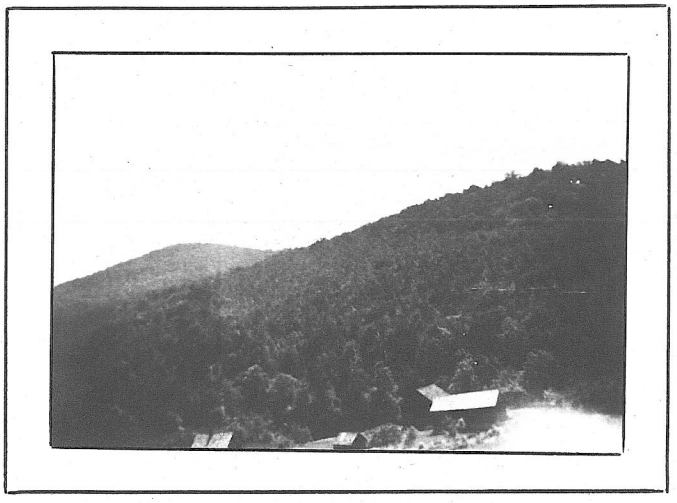


Preglacial valley in the extreme western part of the area

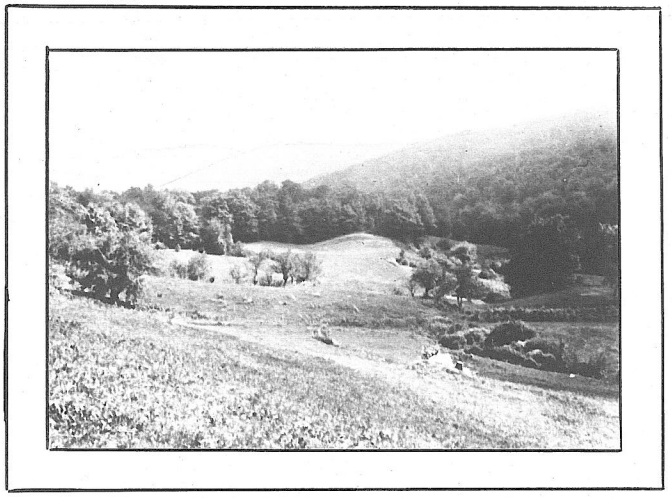


Large preglacial valley in the extreme eastern part of the region

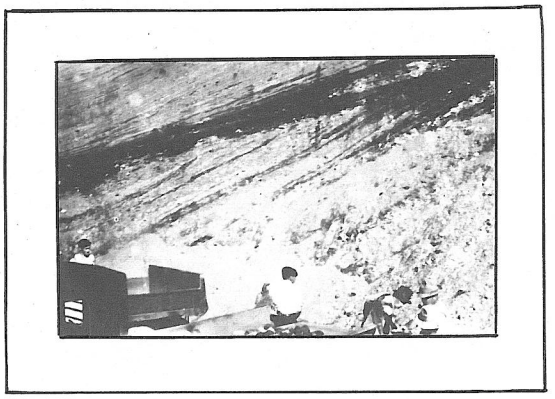
Plate 2.



Middle slope on western side of the Auger Hole



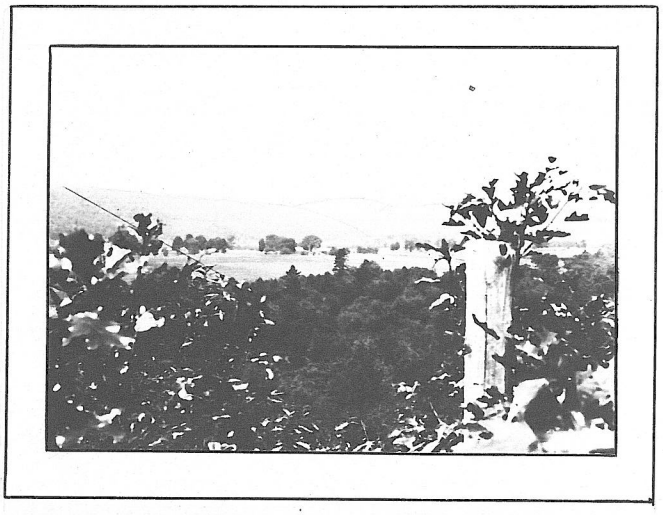
Typical moraine topography in the Auger Hole



Cross section of glacial outwash plain at h-19

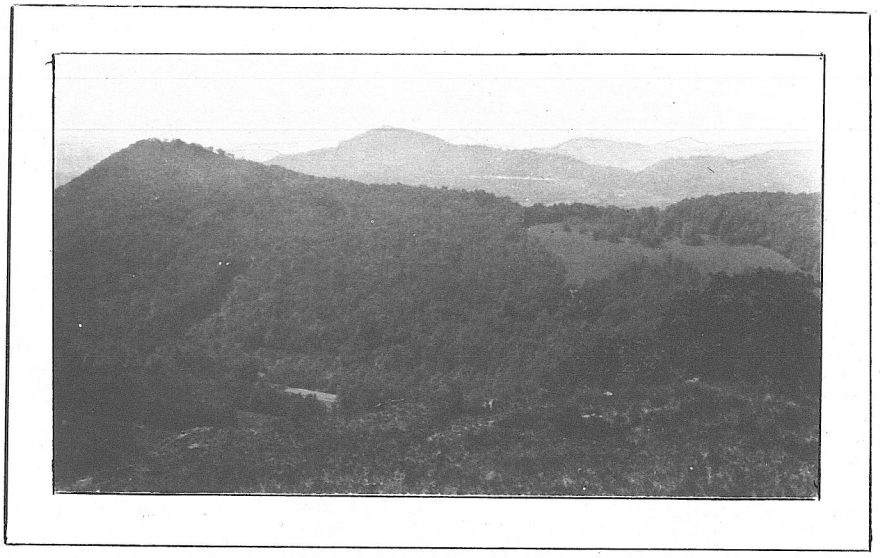
Plate 3.

Alluvial fan in the
Auger Hole

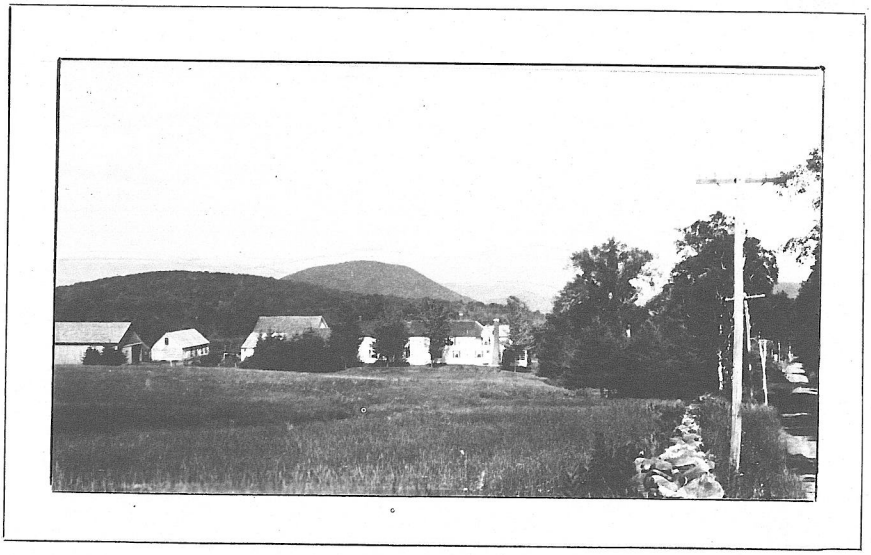


Preglacial valley in the
southern part of the area

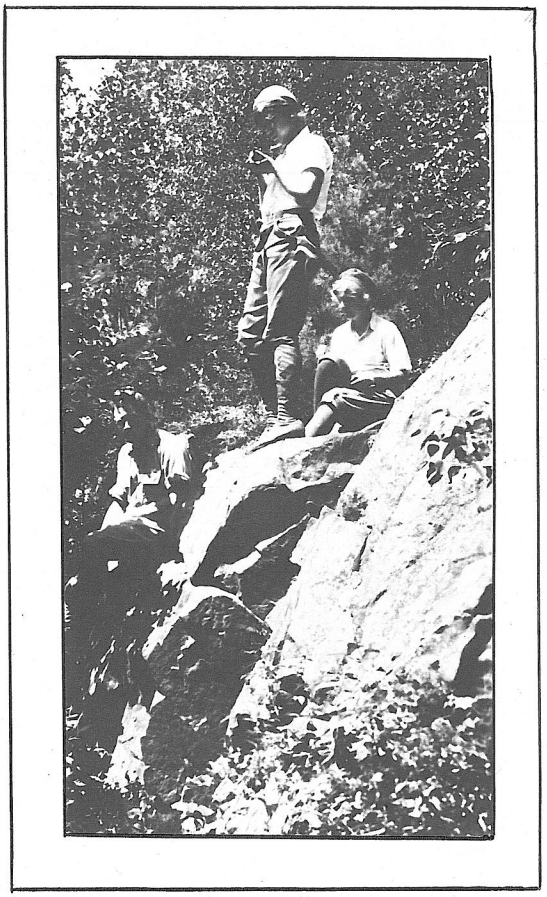
Plate 4.



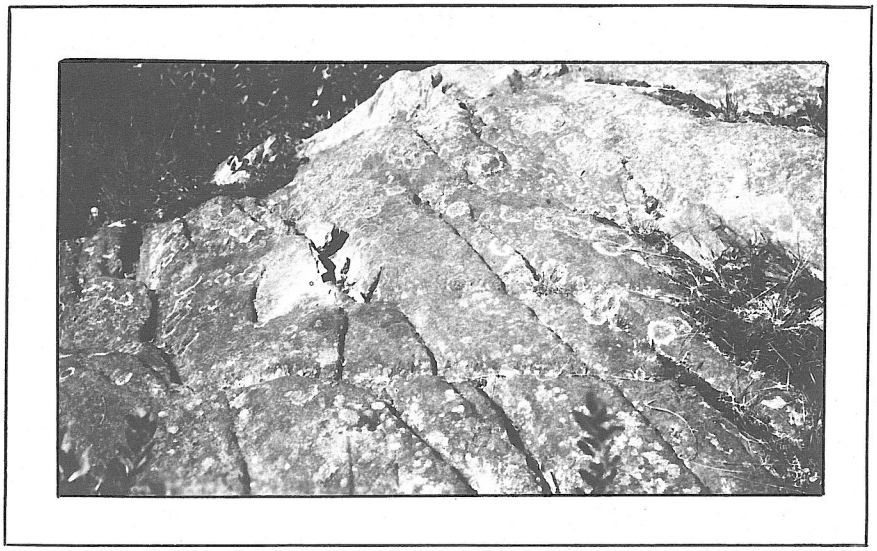
Hogback hills - Hill 1284 in the foreground, Round Mountain, and Ginseng Hill in the background



The second hill is Round Mountain showing the monadnock type of hill

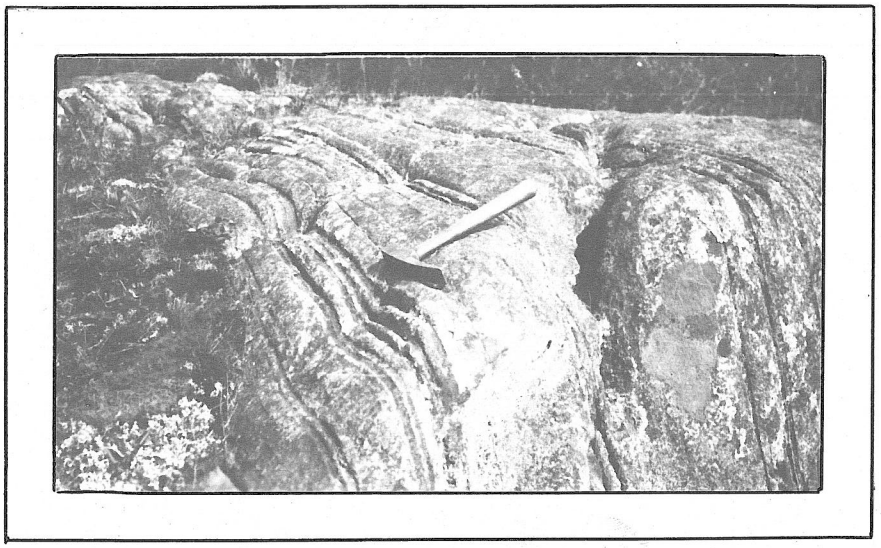


Massive siliceous phase of the Marlboro Schist, typical of the northern part of the formation

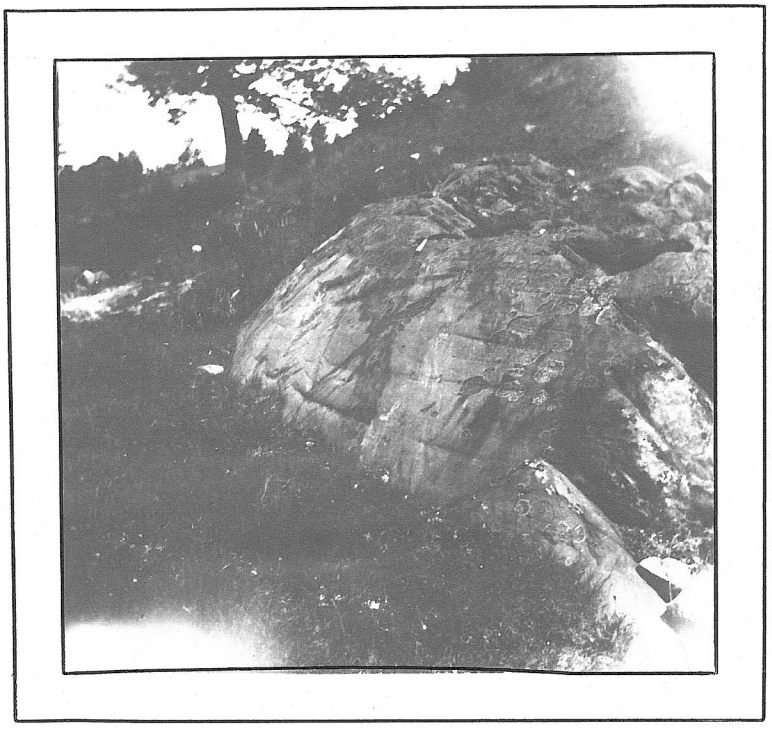


Typical outcrop of the porphyroblastic phase of the Marlboro Schist showing jointing

Plate 6.

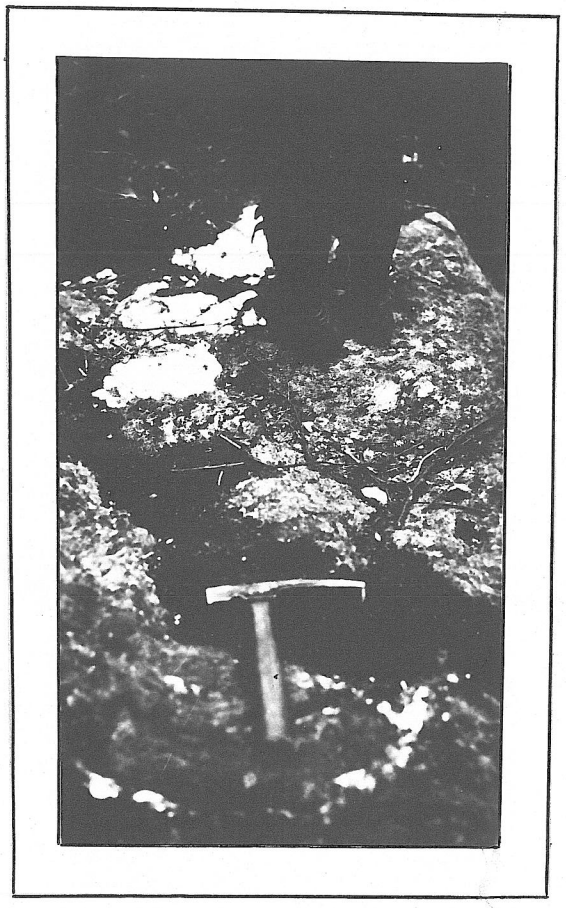


Bedding planes in the Whetstone member of the Ames Hill Schist

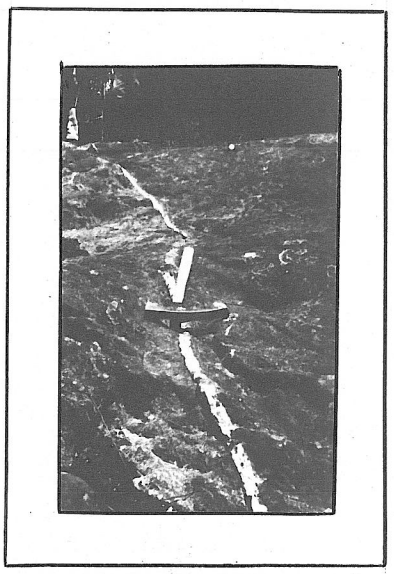


Central core of hornblendic igneous mass in western part of the area

Plate 7

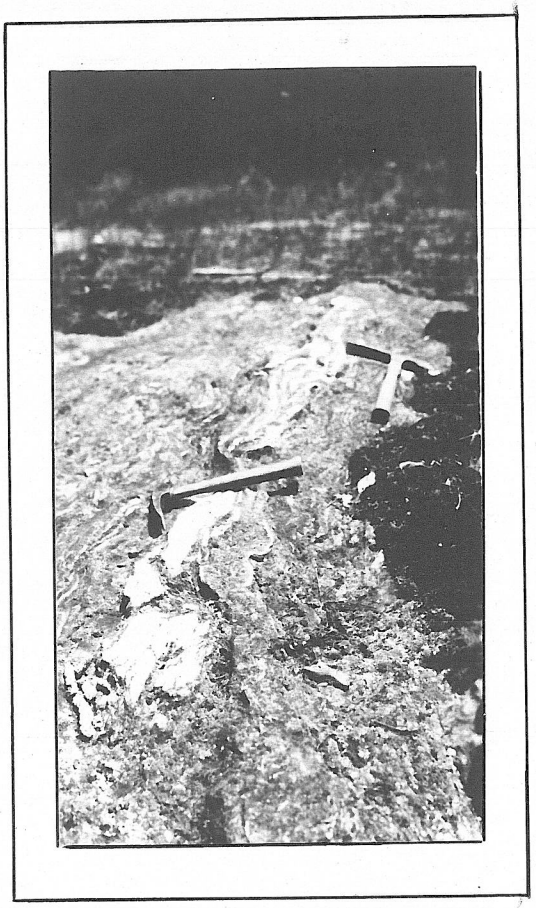


Discontinuous acid dike, a portion parallel to schistosity, and the remainder at an angle.

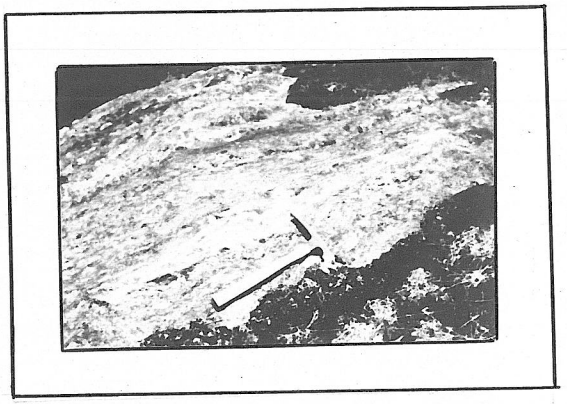


Small quartz vein cutting across schistosity

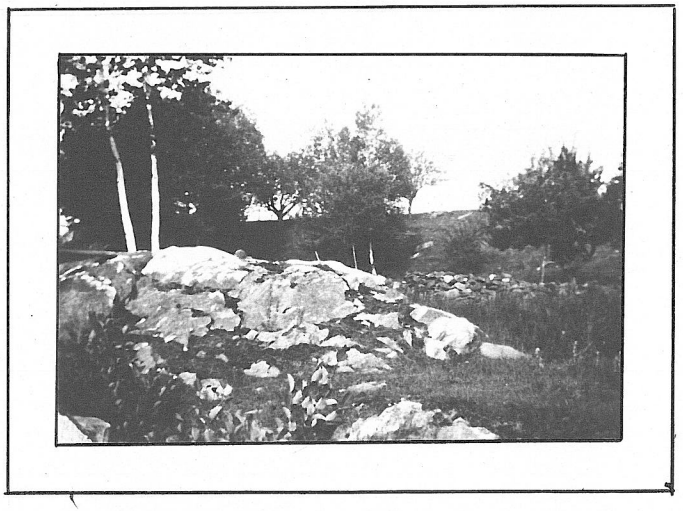
Acid dike dividing into two separate veins



Acid dike following the planes of schistosity

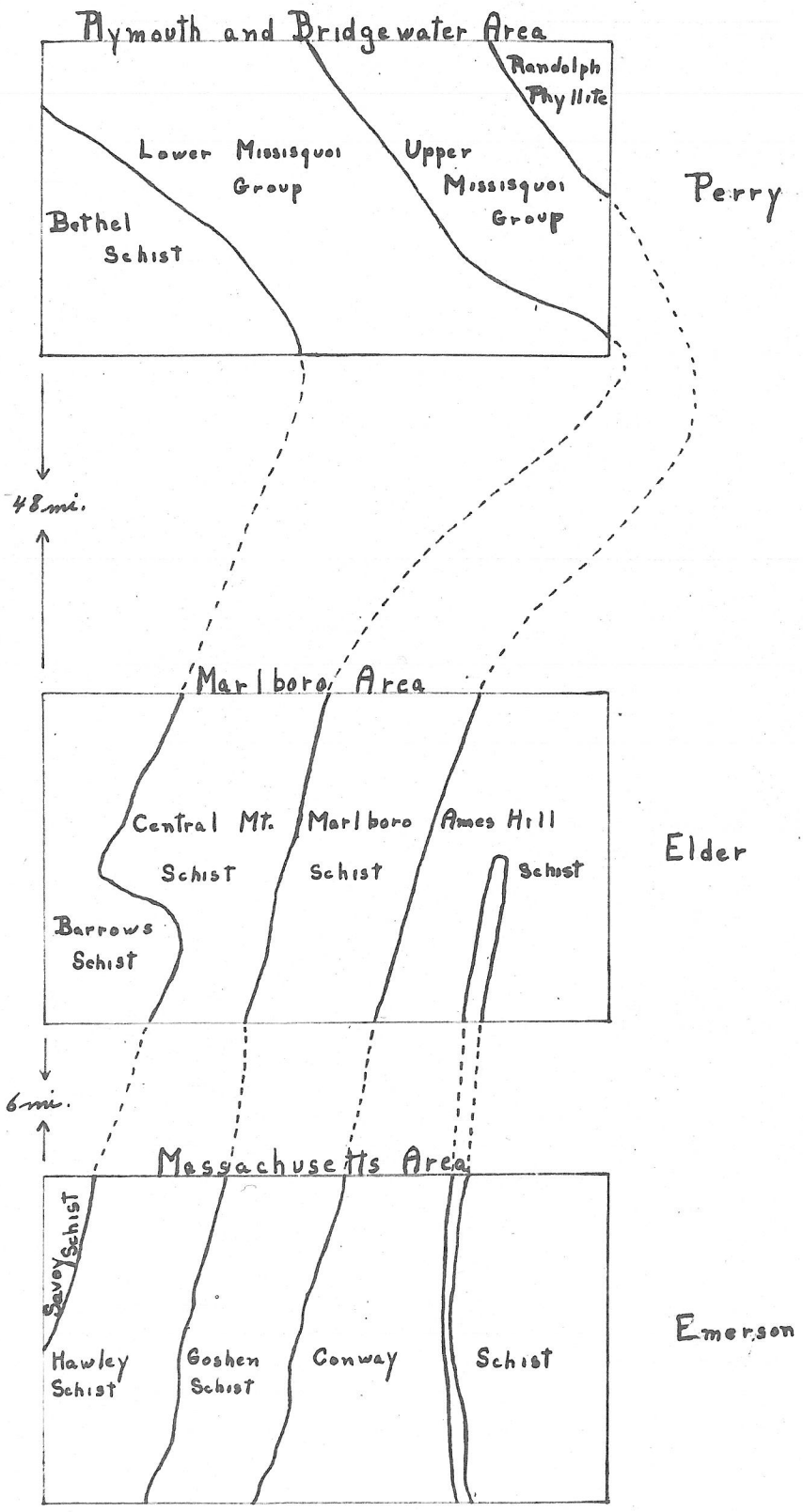


Thin quartz veins intruded parallel to schistosity



Quartz dike intruded at an angle to schistosity

Plate 9.



Correlation Map

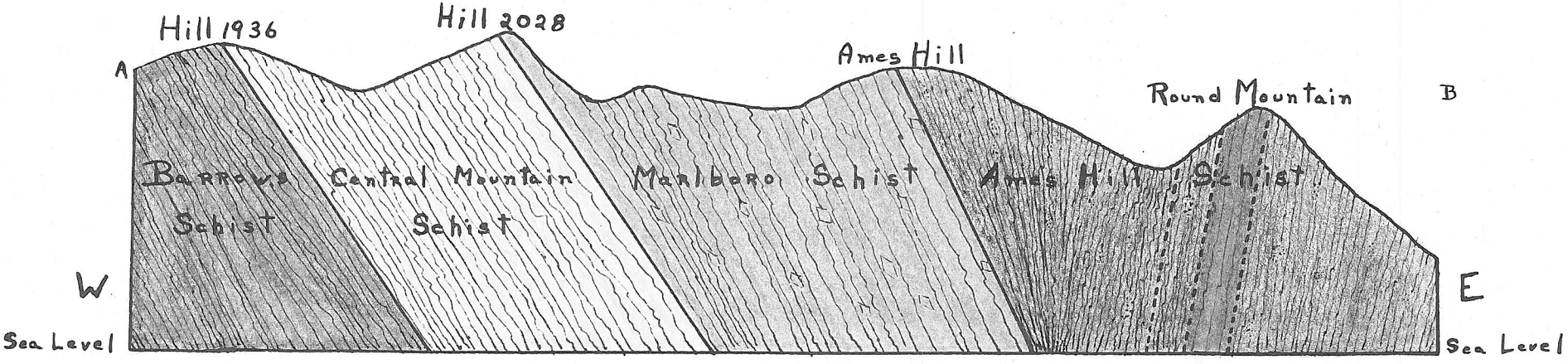
Scale of areas - 3 miles - 1 inch

Exaggeration N. and S. between areas

Correlation Chart

Perry - 1927	Richardson - 1927	Emerson - 1917	Hubbard - 1924	Elder - 1930
Memphremagog Group (Randolph Phyllite) Dark grey strongly foliated, graphitic looking mica-schist with garnets. (Waits River Limestone) Weathers readily to a porous seal brown rock on exposed surfaces. Complete break with underlying Missisquoi Group.	Memphremagog Group (Randolph Phyllite) Fine grained, graphitic phyllite structure. Contemporaneous with Waits River limestone.	Conway Schist Finely corrugated muscovite schist, dark from abundance of graphitic matter, with garnets, many beds of a sandy quartzite, beds of black limestone and numerous beds of hornblende schist.	———	Ames Hill Schist Finely placated lead blue garnetiferous schist with numerous siliceous lenses and with a thick lens of hornblende schist. Distinct break with underlying Marlboro formation.
Upper Missisquoi Group Fairly uniform quartz-mica schist with quartzites and numerous bands of hornblendic rock.	Missisquoi Group (Quartzite) (Chlorite Schists) (Hornblende Schists) Quartzite grading into sericite, chlorite and hornblende schists. Hornblende schists are lenticular.	Goshen Schist Dark grey muscovite schist with a bed of hornblende schist of sedimentary type.	———	Marlboro Schist Variable grey siliceous to green micaceous schist with numerous porphyroblastic lenses.
Lower Missisquoi Group Non-uniform garnetiferous mica schist.	Missisquoi Group (Gassetts Schist) Silvery white, highly garnetiferous, muscovite schist. Towards south, biotite replaces sericite.	Hawley Schist Soft dark green chlorite schist with beds of black hornblende.	———	Central Mountain Schist Light green garnetiferous schist with occasional hornblende layers.
Bethel Schist Grey-green, quartz-chlorite-muscovite schist, locally garnetiferous. Time equivalent of Richardson's Cavendish Schist.	Cavendish Schist Quartz biotite schist with hornblende sometimes replacing nearly all of the biotite.	Savoy Schist Alternating siliceous and hornblende beds.	Halifax Schist Chlorite formation with some bands rich in hornblende and others rich in quartz.	Barrows Schist Alternating hornblende and black to green siliceous horizons.

Plate 10.



Cross-Section of Area

Horizontal scale - 1 mile - 1 inch Vertical scale - 1000 feet - 1 inch

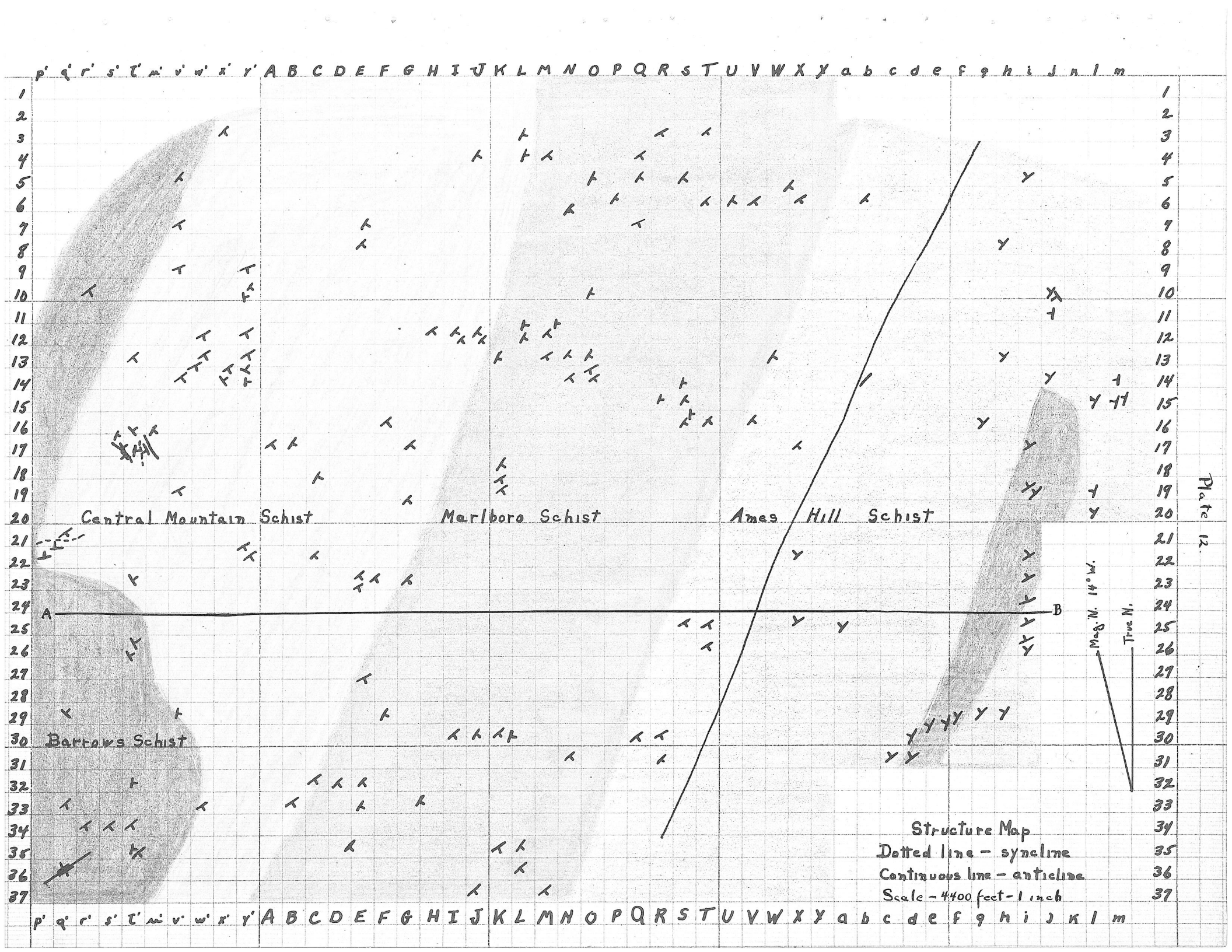
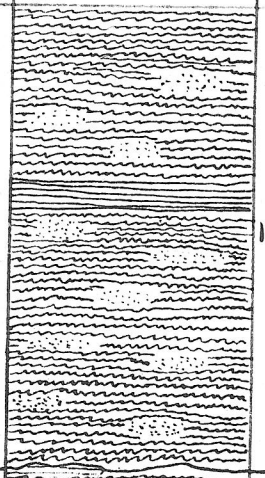

Central Mountain Schist
Marlboro Schist
Ames Hill Schist
Barrows Schist
A
B
Mag. N. 14° W.
True N.
Structure Map
Dotted line – syncline
Continuous line – anticline
Scale – 4400 feet – 1 inch

Plate 12.

System	Series	Formation	Symbol	Columnar Section	Thickness	Character of Rocks	Character of Topography
Ordovician(?)	Beekmantown	Ames Hill Schist	Oah		12000 ft. +	Finely plicated lead blue garnetiferous schist with numerous siliceous lenses and with a thick lens of hornblende schist	Rolling and hilly Topography
Cambrian (?)	Croixian	Marlboro Schist	$\mathcal{C}$m		9000 ft. ±	Variable gray siliceous to green micaceous schist with numerous porphyroblastic lenses	Hilly topography
		Central Mountain Schist	$\mathcal{C}$cm		7000 ft. ±	Light green garnetiferous schist with occasional hornblende layers	Hilly topography
		Barrows Schist	$\mathcal{C}$b		3000 ft. +	Alternating hornblende and black to green siliceous horizons	Rolling Topography

Columnar Section

scale 1 inch – 5000 feet

Plate 13.